M.S. Thesis in Education

EFFECTS OF WORKED EXAMPLE FORMATS AND PRIOR KNOWLEDGE LEVEL ON MENTAL EFFORT AND ACADEMIC ACHIEVEMENT FOR PROBLEM SOLVING SKILLS

by

Yan Liang

August 2012

Department of Education

Graduate School of Seoul National University

EFFECTS OF WORKED EXAMPLE FORMATS AND PRIOR KNOWLEDGE LEVEL ON MENTAL EFFORT AND ACADEMIC ACHIEVEMENT FOR PROBLEM SOLVING SKILLS

by

Yan Liang

Academic Advisor: Cheol Il Lim, Ph.D

Submitted to the Department of Education and the Faculty of the Graduate School of Seoul National University

In partial fulfillment of the requirements for the Degree of Master's in Education

August 2012

Approved by the Committee:

Chair	Dr. Ilju Rha	____________________
Vice Chair	Dr. Seong Ik Park	____________________
Committee	Dr. Cheol Il Lim	____________________

ACKNOWLEDGEMENTS

A number of individuals have provided me with assistance and supports over past 2 years while my working on the master’s degree. To these, I would like to give my great appreciation.

To Dr. Cheol Il Lim, my major professor.

Thank you for giving me invaluable guidance, support, encouragement, kindness and sincere advice.

To my committee, Dr. Ilju Rha, Dr. Seong Ik Park.

Thank you for the suggestions, assistance and professional insight.

To my parents.

Thank you for your love, understanding, support and encouragement throughout the course of my study.

ABSTRACT

Considerable attention has been directed toward the value of studying worked examples where learning is enhanced and cognitive load could be reduced through the process provided in worked examples. Although previous research has shown the effectiveness of worked example in instruction, very little work has been done to investigate the effects of the different worked example formats on mental effort and achievement intermediating with learners' prior knowledge level. This study is attended to explore the effects of different worked example formats and prior knowledge level on mental effort and academic achievement for problem solving skills.

One hundred and fifty-two first-year students from a middle school in China participated in this study. Based on the pre-test, they were divided into two levels of prior knowledge: high and low. Participants in each level were randomly assigned to one of the two treatment conditions- instruction with process-oriented worked example and instruction with product-oriented worked example. After the lesson, they were given the mental effort and post-test.

Test the hypotheses, a 2×2 (worked example formats × prior knowledge level)subject factorial design was employed. To compare the main effects of the two different types of worked example (process-oriented and product-oriented), a T-test was employed. In addition, to compare the interaction effect of worked examples and prior knowledge level a two way analyses of variance (ANOVA) was employed. For all tests, the alpha level was set at .05.

The results of the study indicated that there was no significant difference for learner's achievement. However, compared to produce-oriented groups, mean achievement scores of process-oriented worked example groups showed a little higher for low prior knowledge learners and slightly lower for high prior knowledge learners. For the mental effort, the results revealed that the mental effort were greater among high prior knowledge learners with product-oriented worked example and less among low prior knowledge learners with process-oriented worked example instruction. That is, the high prior knowledge learners benefited more from product-oriented worked example and low prior knowledge learners benefited more from process-oriented worked example.

The findings of this study support the expertise reversal effect that may happen in instruction with the intermediation of learners' prior knowledge level. The results of this study suggest learners' prior knowledge level should be considered when designing learning strategy for complex problem solving skills. Due to the lack of fully randomized design and the short treatment time, the results and interpretation are tentative. Further studies to verify the results are recommended.

Keywords: problem solving, worked example formats, process-oriented worked example, product-oriented worked example, prior knowledge, mental effort

***Student Number*: 2010-24150**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

1. Problem Statement and Purpose of Study

In modern life, almost every context presents a deluge of problems that demand solutions. People need to learn how to solve problems in order to function in their everyday and professional lives (Jonassen, 2005). Solving problem is defined as a complex cognitive skill that characterizes one of the most intelligent human activities (Chi & Glaser, 1985). When it is the situation of education, such a practical need demands educators to teach learners with proper problem solving skills (Lim, 1997; Song, Grabowski, Koszalka, & Harkness, 2006).

Problem solving skill is highly valued. For most of this century, many theorists and educational institutions have placed a heavy emphasis on this ability for different people, from children to adults, and experts to novices (Dewey, 1910, 1916). The differences of people are based on cognitive processes and mental organizations that humans have in common, and that characterizes their problem solving abilities. A large number of related researches have discussed both practical and academic significance of the problem solving abilities.

Information and computer technologies and more specific the World Wide Web are receiving increased attention in education because of their potential to support fostering problem solving learning abilities. Web-based learning resources are demonstrated to have the potential to support a learning environment in which learners explore knowledge and enhance their learning (Combes & Valli, 2007). Especially in problem solving learning, learners are required to collect necessary information. With the help of internet technology, learners can easily find the information immediately regardless of time and location.

The web-based learning environment includes many resources, support collaboration, implement web-based activities as part of the learning framework, and support both novices and experts (Sherry, 1996). In web-based environment, learners have the potential of discussing, problem solving, querying their own peers as well as knowledgeable adults in a particular field. Moreover, in web-based learning instruction, it allows learners to meet their own special needs in a self-paced and self-assessing environment. Learners can have a choice of content, time, feedback, and a wide range of media for expressing their understanding. As a result, this study focused on using a web-based environment to develop problem solving skills.

When solving a problem, learners usually attempt to retrieve everything that they know about solving that kind of problem. According to information processing models, the retrieved knowledge is transferred into working memory which holds information for a short time. Due to the limitation of working memory, if the learners have no elements related with the problem being solved, the working memory is easily overloaded. The overload can demand working memory, which will make problem more difficult.

One way to reduce the demand on working memory is to retrieve better-organized and more integrated memories about the problem. A common conception is schema. According to Sweller (1994), learners have to acquire schema to solve cognitive problems. During the construction of a problem representation, certain features of the problem may activate knowledge in memory. A schema for that particular type of problem may then be activated. The schema is a cluster of knowledge related to a problem type. It contains information about the typical problem goal, constraints, and solution procedures useful for that type of problem (Gick & Holyoak, 1983). Schema acquisition constitutes a primary factor determining problem solving skill (Sweller, 1988). If schema activation could occur during the construction of a problem representation, then the solver can proceed directly to the third stage of problem solving (i.e., the implementation of solution strategies and procedures contained in the schema).

Many strategies are provided to help learners acquire schema. One of the instructional strategies that have been found to promote schema and skill acquisition is to use worked examples (Darabi, Nelson, Meeker, Liang, & Boulware, 2010). The schema can be acquired through well-designed instructions including worked example strategies. Numerous researches investigated the efficiency of using worked example instructions and provided evidences on the effectiveness (Carrol

1994; Cooper and Sweller 1987; Paas and van Merriënboer 1994; Sweller and Cooper 1985; Zhu and Simon 1987).

In order to increase learners' problem solving abilities and understanding of key ideas related to the problem, it is necessary to teach learners using an organized problem solving approach that explicitly shows them all the steps involved in the problem solving process to help them address new problems in a systematic manner. A worked example refers to a step-by-step demonstration of how to perform a task or solve a problem (Clark, Nguyen & Sweller, 2006). Worked examples can be used to teach problem solving skills (Moreno, 2006). Generally, there are two steps involved. First is modeling the process of problem solving in a well-structured domain such as physics or mathematics by presenting an example problem. Then demonstrate the solution steps and final answers to the problem (Renkl, Stark, Gruber, & Mandl, 1998). A sequence of worked example is sufficient to induce problem solving thematic skills if carefully designed, even when instruction is absent (Zhu & Simon, 1987).

From several classic studies which prove the effectiveness of learning from worked examples, Sweller and his colleagues found that, compared to learning by solving problems, where learners are asked to engage in mean-ends analyses, learning with example-problem pairs, where one example is followed by isomorphic problems to be solved, increased near transfer (Mwangi & Sweller, 1998; Sweller & Cooper, 1985; Tarmizi & Sweller, 1988; Ward & Sweller, 1990). Novices, especially, not possessing appropriate schemas, are not able to recognize and memorize problem configurations and are suggested to use general problem solving strategies such as means-ends analysis when faced with a problem.

The finding which demonstrates that example-based learning is more effective for problem solving skill acquisition than the standard procedure of solving problems, has been called the worked-example effect in the cognitive load literature (Sweller, Van Merriënboer, & Paas, 1998).

Cognitive load theory explains learning outcomes by considering the strengths and limitations of the human cognitive architecture and deriving instructional design guidelines from our knowledge about how the human mind works (Paas, Renkl, & Sweller, 2003). The main tenet of cognitive load theory is that instruction should be designed in a way of considering the structures that constitute human cognitive architecture, which is effective for schema construction and automation. The basic assumptions underlying cognitive load theory are that the human information processing system is characterized by the following: working memory—capacity which is considered limited that only a few piece of information can be actively processed at any one time (Baddeley, 1992); long-term memory which consists of a vast number of hierarchically organized schema (Paas et al., 2003); and automatic processing which means that after being sufficiently practiced, schemas can operate under automatic processing and therefore require minimal working memory resources (Kalyuga, Ayres, Chandler, & Sweller, 2003).

When learning complex tasks, many information elements contained are new and interactive, and they have to be processed simultaneously in working memory for learning to be achieved (Chandler & Sweller, 1991). Consequently, such tasks can impose a high working memory load. This cognitive load imposed by the interactive elements which a task contains is called intrinsic cognitive load (Sweller et al., 1998). Besides, the prior knowledge of the learner can influence intrinsic cognitive load in the way when learning progresses information elements are combined into schema that can be treated as one element in working memory. Working memory capacity is considered limited to seven plus or minus two elements or chunks of information (Miller, 1956). As a result, the higher the prior knowledge of a learner, the lower the intrinsic load a task imposes. In the process of dealing with a problem, schema acquisition happens first so that information and measurements taken on the system have to be processed in working memory simultaneously. Then is schema automation (Schneider & Shiffrin, 1977) which can further reduces cognitive load by allowing learners to bypass the limited capacity working memory. By using automated schemas, learners can invest less mental effort to reach an optimum level of performance.

Sweller and his associates described two additional types of cognitive load that instructional designers may control, as they structure the manner in which instruction is presented (Sweller, van Merriënboer, & Paas, 1998). One is called extraneous cognitive load as it is ineffective for learning. The other is germane load as it is effective for learning. These two forms of cognitive load are associated with the presentation of instructional material. Sweller et al. (1998) stated that learning could take place through solving problems with weak strategies such as means-ends analysis which novice learners often used, but it would be a slow process. Although mean-ends analysis is effective for obtaining solutions to problems, it imposes a relatively high extraneous load and consequently reduces the cognitive resources available for learning (i.e., schema acquisition and automation). Particularly, under conditions of high intrinsic load, the use of these strategies can easily overload working memory, which does not foster effective learning.

Use of worked examples in instruction can reduce the extraneous load, because learners do not have to devote cognitive resources to weak problem solving strategies. Worked examples can help learners invest all available resources in studying the solution and constructing and automating a cognitive schema for solving problems.

In recent research of worked examples, most studies are associated with complex cognitive tasks (Hoogveld et al. 2005; Joung 2006). Van Gog et al. (2004, 2006) divided worked examples into product- and process-oriented worked examples. Their studies mainly focused on the effectiveness of the process-oriented worked examples and the sequences of these two kinds of worked examples on the transfer. Besides Joung (2006) tried to divide a worked example into parts as a strategy to resolve complex cognitive problems. She assumed that if parts of a worked example would be practiced first, a complex cognitive task such as computer programming could be solved better. Therefore, she divided a worked example into ‘‘the product-oriented whole task approach’’ and ‘‘the process-oriented part task approach.’’ The researcher supposed that the latter approach would be more effective. However, the result turned out to show that the former approach was superior to the later. In addition, some research demonstrated that a heavier reliance on worked examples lead to lower acquisition time (Sweller & Cooper, 1985; Van Gog, Paas, & Van Merriënboer, 2006; Zhu & Simon, 1987), lower cognitive load which was experienced by learners during instruction (Paas & Van Merriënboer, 1994; Van Gog et al., 2006), and lower cognitive load which was experienced by learners during the test (Paas, 1992; Paas & Van Merriënboer, 1994).

It should be noted that though the beneficial effects of worked examples on learning outcomes, acquisition time, and transfer, compared with problem solving, seem to apply primarily to low prior knowledge learners; for advanced learners who have more prior knowledge of the problem solving procedure, worked examples may no longer be effective or may even hamper learning (Kalyuga, Chandler, Tuovinen, & Sweller, 2001; this is an example of the ‘expertise reversal effect’, see Kalyuga, 2007; Kalyuga, Ayres, Chandler, & Sweller, 2003).

The expertise-reversal effect might happen in the van Gog et al. (2006) experiment: adding process information to worked examples might initially impose a germane load and lead to higher efficiency, but it might become redundant, impose an extraneous load, and start to hamper learning when training progresses and knowledge increased. However, it was not possible to corroborate this hypothesis based on their data.

Consequently, in this study it extended the research of effectiveness for using worked examples in instruction with the consideration of individual differences of learners. Since the expertise-rehearsal effect may occur with different worked example formats that induce a germane load for learners with different prior knowledge levels. It assumed that the process-oriented and product-oriented worked examples instruction would have a different effect on learner's achievement and mental effort. It also considered the prior knowledge of learners as an important factor in the cognitive process. Besides, the web-based learning environment was a critical element that affected learning achievement. In many previous studies (Carrol 1994; Cooper and Sweller 1987; Sweller and Cooper 1985; Zhu and Simon 1987), the effectiveness of worked examples was examined in the traditional classroom. However, in this study the learning environment was web-based environment which tended to examine the effects of worked examples in self-regulated learning environment.

2. Research Questions

Research questions of this study are as follows:

1) What effect do different formats of worked examples (i.e. process-oriented or product-oriented worked examples) have on learners' academic achievement in web-based learning environment?
2) What is the interaction effect between different worked example formats and learners' prior knowledge on mental effort in web-based learning environment for solving problem?
3) What is the interaction effect between different worked example formats and learners' prior knowledge on academic achievement in web-based learning for solving problem?

3. Definition of Terms

Throughout the dissertation, various words or abbreviations with specific meanings are used. As an advanced organizer for these terms, this section provides a centralized place of the definitions.

Web-Based Learning for Problem Solving

Web-based learning for problem solving refers to the learning environment in which a hypermedia-based instructional program that utilizes the attributes and resources of internet to create a meaningful learning environment where problem can be solved effectively (Khan, B. H. (1997). In this study, the problem solving is defined as getting from an initial problem state to desired goal state (Newell & Simon, 1972). The pedagogical tools were enabled by the internet and web-based technologies that could facilitate learning and building knowledge through the meaningful action and interaction.

Prior Knowledge

Prior knowledge is identified as information mastered and maintained from previous experiences, whether from earlier classroom lessons or from life experience. Prior knowledge can also be explained as a combination of the learner's preexisting attitudes, experiences, and knowledge (Kujawa & Huske, 1995).

Worked examples

Worked examples show a problem state, a goal state, and the solution steps that lead from the problem state to the goal state (i.e., the solution procedure). In cognitive load theory (Sweller, 1988; Sweller et al., 1998; van Merriënboer & Sweller, 2005), worked example effect is explained in terms of reduced extraneous or ineffective working memory load, which allows for better schema construction and automation.

Formats of Worked Examples

Van Gog et al. (2004) identified process-oriented and product-oriented as two types of worked examples. Product-oriented worked examples describe the procedures involved in solving a problem by providing learners with an initial state, a goal state, and a set of solution steps. Process-oriented worked examples, on the other hand, explain not only how to solve a given problem but also why the operations are employed.

Mental effort

The measurement of mental effort reflects the actual cognitive load in the real problem solving process. The mental effort was measured by using Pass's 9-point rating scale (1992).

II. REVIEW OF THE LITERATURE

1. Problem Solving

1) Problem Solving

Problem is identified to have two critical attributes (Jonassen, 2004). First, problem refers to the difference between a goal state and a current state of an unknown entity in some context. Second, there is much social, cultural, or intellectual value for finding or solving for the unknown problem. If a problem is unknown and worthy of solving, then problem solving is “any goal directed sequence of cognitive operations” (Anderson, 1980, p. 257) directed at finding that unknown.

Problem solving is defined as getting from an initial problem state to a desired goal state, without knowing exactly what actions are required to get there (Newell & Simon, 1972). Similarly, there are two critical attributes for problem solving operations. First, problem solving requires the mental representation of the problem and its context. That is, human problem solvers construct a mental representation (or mental model) of the problem, known as the problem space (Newell & Simon, 1972). Although there is little agreement on the meaning of mental models or problem spaces, internal mental models (as opposed to social or team mental models) of problems are multimodal representations consisting of structural knowledge, procedural knowledge, reflective knowledge, images and metaphors of the system, and executive or strategic knowledge (Jonassen and Henning, 1996). Second successful problem solving requires that learners actively manipulate and test their models. Thinking is internalized activity, especially when solving problems, so knowledge and activity are reciprocal, interdependent processes (Fishbein and others, 1990).

Gagne (1985, 1987) has defined problem solving as the highest order of thinking skills. In the majority of research into this area, problem solving is seen as 'a process by which the learner discovers a combination of previously learned rules that he can apply to achieve a solution for a novel problem situation' (Gagne 1977), and the focal points of investigation have been the strategies adopted by learners in this process and the conditions.

2) Problem Solving Process

Problem solving is defined as a process in which people perceive and resolve a gap between a present situation and a desired goal, with the path to the goal blocked by known or unknown obstacles (Huitt, 1992). Problem solving is a hard process because it places cognitive demand on the learners.

When faced with a problem, a learner always tries to retrieve everything he knows about solving that kind of problem. In this process, complex problem solving activities are usually involved (Zawojewski & Lesh, 2003). According to the information processing models, knowledge is retrieved into the working memory which is a temporary memory buffer that holds the information for a short time. Then the new knowledge from the sensory memory can be processed together to save the new knowledge in the long-term memory in the end. Figure II-1 represents the diagram how the information is processed (Atkinson & Shiffrin, 1968).

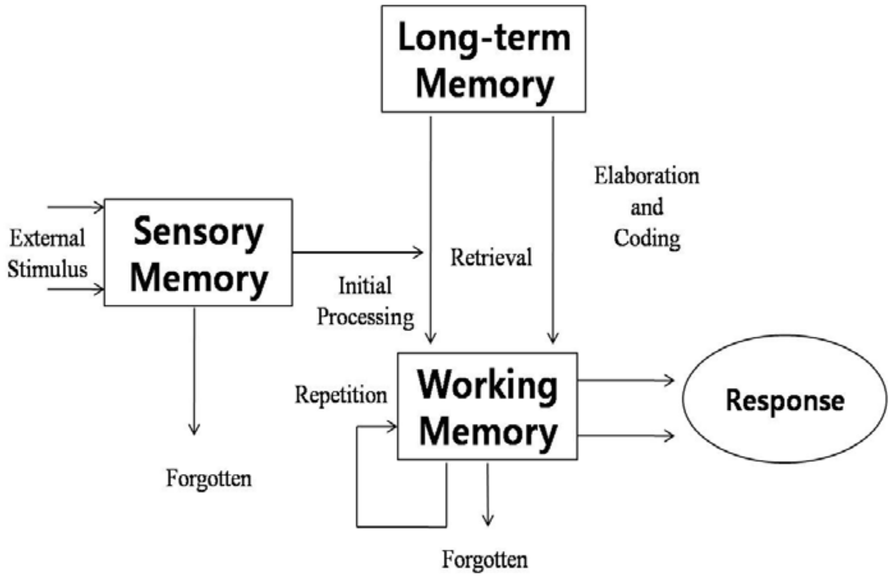


Figure II-1. Diagram of information processing model (Atkinson & Shiffrin, 1968)

However, the capacity of working memory is limited so that only a few things can be kept in mind at a time—usually to seven plus or minus two items.

Consequently, when learners retrieve knowledge about how to solve the problem, plus having to deal with the elements of the current problem they are trying to solve, the working memory is overloaded. Especially when no procedures are involved in the process of problem solving, the demands on working memory can make problem more different.

If better organized and more integrated memories about the problem solving are retrieved in the working memory, the demands can be reduced. There is a mechanism involved to circumvent the limits of working memory, which is schema (Wilson & Cole, 1996). Schema refers to a cognitive representation of a construct (an idea, concept, process, or phenomenon, for example). It is a goal-oriented cognitive mechanism and the goal is to solve the problem (Callison, 1998). For a problem, the schema consists of what the kind of problem is, the structural elements of the problem, and situations in which such problems occur, and the processing operations required to solve that problem (Jonassen, 2003). The size of a scheme is not fixed. It can be large or small. When the schemas for a problem is well organized and integrated, they can be brought to working memory as a whole chunk. As working memory can only process several chunks of information. The better the schemas are organized, the less demands can be placed on the working memory. Schema acquisition allows people to chunk information into meaningful units. Since schema results from a repetition of similar experiences, with much practice and reflection, the schema can become accumulate and automated for different kinds of problem solving. That is the reason why high prior knowledge learners are better problem solvers than low prior knowledge learners. When high prior knowledge learners solve problem, the schemas provide them numerous information about how the mind understands and processes information which include conceptual knowledge, processing operations, and fix-up strategies.

3) Web-Based Problem Solving Learning

The web-based learning environment is defined as web-based courses and programs which have increasingly been developed by many academic institutions, organizations, and companies worldwide due to their benefits for both learners and educators. Haury and Milbourne (1999) studied ways of incorporating web-based contexts for learning science which resulted in eight major areas: (1) facilitating productive interactions; (2) finding new sources of information; (3) seeking assistance; (4) staying informed; (5) extending classroom activities; (6) doing research; (7) getting involved in projects; and (8) enriching personal experience. Moreover, many studies have demonstrated that web-based learning increases learner's interest and intrinsic motivation for learning (Seng & Mohamad, 2002; Wang & Yang, 2002) as well as facilitates co-operative or collaborative learning (Jung, Choi, Lim, & Leem, 2002; Uribe, Klein, & Sullivan, 2003).

When examining the characteristics of instruction for problem solving and the feature of web-based learning, it is valuable to connect these two in real practice

(Thompson, Martin, Lynne, & Branson, 2003). The combination of these two is due to three considerations. First, the web can supply vast resources for solving problem. The various resources provided in the web can enable learners to search instantaneously for the information they need to solve the problem. Second, the difficulties of solving problems can be dealt through the web-based interactions. The web may be the ideal tool to nurture learners' willingness to take risks, commitment to task, curiosity, openness to experience, problem founding, metaphorical thinking, and breaking away from the norm (Bonk & Reynolds, 1997). Third, research results indicate that web-based learning could arouse learners' interest and motivation for solving problem; and interest and motivation are crucial factors determining learning outcomes.

In short, the web-based learning environment can improve learners' problem solving ability and lead to effective learning outcomes. In addition, it was studied that the web-based teaching materials were one of the important factors that could affect teaching activities in an efficient and effective way in the design and development system (Chang, Sung, & Hou, 2006). The way of how materials are designed can also affect the process of problem solving. As a result, this study focused on using a web-based environment to develop problem solving skills.

2. Prior Knowledge

Prior knowledge refers to all information about the problem available in addition to the training data. In other words, prior knowledge includes information mastered and maintained from previous experiences, whether from earlier classroom lessons or from life experience.

According to information processing theory, memories of prior experience are stored over the long term in a relatively inactive state. When the stored prior knowledge is to be used in the performance of a particular cognitive task, the prior knowledge is brought from the inactive state into an active state. In this active state the prior knowledge can be effectively used in performing the ongoing cognitive task (Britton & Tesser, 1982). The prior knowledge is usually represented in a flow chart as an arrow leading form a long-term memory store to a short term working memory (Atkinson & Shiffrin, 1968).

Prior knowledge is a key component of schema-based theories of reading comprehension and can be explained in four aspects, including the learner's preexisting attitudes, experiences, and knowledge (Kujawa & Huske, 1995). It can influence cognitive processing through schemas. Since schemas are organized structures of prior knowledge, they have been shown to influence perception, learning, and performance (e.g., Schank & Abelson, 1977).

3. Worked Examples and Cognitive Load

1) Worked Examples

A worked example is a step-by-step demonstration of how to perform a task or solve a problem. Worked examples are considered as instructional tools to teach problem solving skills (Moreno, 2006). The worked-example effect occurs when learners presented worked examples to study during a learning phase solve test problems more effectively than learners presented the equivalent problems to solve during the learning phase (Cooper & Sweller, 1987; Paas & van Gog, 2006; Reisslein, Atkinson, Seeling, & Reisslein, 2006; Sweller & Cooper, 1985; van Gog, Paas, & van Merriënboer, 2006).

A large number of studies have proved the effectiveness of worked examples. Sweller and Cooper (1985) were the first to show that using worked example instead of practice problems could same time and result in the same or even more learning as requiring learners to work all problems as practice exercises. Zhu and Simon (1987) reported one field trial in Chinese middle school in which a traditional three-year course consisting of two years of algebra and one year of geometry were successfully completed in two years by using worked examples.

According to Sweller et al. (2006), worked examples could be presented in diverse formats and modalities in instruction design. There were worked example-problem pair lessons, completion worked example lessons, worked out example lessons etc. Van Gog et al. (2006, 2008) divided worked examples into product- and process-oriented worked examples.

Product-oriented worked examples describe the procedures involved in solving a problem by providing learners with an initial state, a goal state, and a set of solution steps. This type of worked example presents the learner with the "product" which an expert has produce at each stage of the problem solving process (van Gog et al., 2004). However, there is limitation for this kind of worked example. It fails to provide leaners with the principled knowledge (domain specific knowledge) necessary for learners to appropriately represent the problem and make the correct selection and application of steps and operators to solve the problem. In other words, product-oriented worked examples do not explain "why" certain steps are taken during the problem solving process (van Gog et al., 2006). Since knowledge of a domain consists of principled knowledge and its teleology, learners need to understand the principles underlying the solution, and why these steps are taken in a particular order (van Gog et al., 2004)

While process-oriented worked examples explain not only how to solve a given problem but also why the operations are employed. This kind of worked examples are comprised of solution steps, and both strategic and principle (i.e., declarative) information would enhance learners' understanding and transfer performance (van Gog et al., 2004, 2006). It expands beyond the presentation of solution steps providing both the how (strategic) and why (principled) behind the problem steps.

In this study, these two formats of worked examples were examined as one kind of the independent variables.

2) Worked Examples and Cognitive Load

Worked examples instruction represents one of the major instructional methods based on cognitive load theory (Sweller et al., 1998). From the perspective of cognitive load, worked examples are example-based methods that minimize learners' use of cognitive resources in learning activities. When studying worked examples, by focusing learners' attention on problem states and problem solving operators or moves, limited working memory capacity can be devoted to building a schema of how to perform the task so that the load on working memory can be lessened (Sweller, 1988, 1994).

Having a worked example to study just prior to solving a similar problem provides the learner with an analogy available while solving the problem. If learners have to solve a problem without the benefit of an analogous example, most working memory capacity is used up in figuring out the best solution approach, with little remaining for building a schema. In other words, when using worked examples for problem solving, rather than engaging in extensive search processes to produce the correct solution steps to solve the problem, learners who study examples can use their limited cognitive resources for the induction of abstracted and generalizable problem solving schemas that can be used to solve future problems with the same underlying structure (Sweller, 1988, 1994; Sweller et al., 1998).

Paas (1992) found that worked examples were superior to straight practice for learning of statistical concept mean, median, and mode. In his experiment, the participants rated the lessons with worked examples as significantly less difficult than the lessons with all practice, which suggests that the benefit of worked examples is due to reduce cognitive load.

In sum, the worked-example effect is the result of a practice method that makes a more efficient use of learners' limited cognitive resources than the one resulting from problem solving practice.

4. Relations among Worked Examples, Prior Knowledge, and Problem Solving

1) Prior Knowledge and Problem Solving

Prior knowledge has a substantial influence on cognitive processing in the area of problem solving (Larkin et al., 1980). In problem solving, differences in prior knowledge between high and low levels produce differences in the probability of problem solution, time to solve, and quality of solution (e.g., Larkin, McDermott, Simon, & Simon, 1980).

When prior knowledge is combined with cognitive problem solving, if the completed solution of the task is already stored in the memory and is easily accessible, the prior knowledge will probably reduce the use of capacity (Britton & Tesser, 1982). For example, if the learner is asked to solve the multiplication problem 37 x 8, a lot of mental operations will be carried out to arrive at the correct answer of 296. However, if the learner is immediately asked again to do the same multiplication problem of 37 x 8, the prior knowledge of the answers will be retrieved from memory, and the effect will reduce the number of mental operations and so the use of capacity.

It is the same situation in problem solving; the high prior knowledge learners can retrieve the solution to a complex problem from long-term memory because they have already stored it there. When solving the problem, they use less capacity than low prior knowledge learners who have to go through all of the process steps on the path to the solution.

2) Worked Examples and Problem Solving in Web-Based Learning

The traditional approach to solving problems is means-ends analysis. It refers to the process by which learners identity the goal and work backward to figure out what needs to be done next. But the use of this strategy seems to hinder schema learning (Owen & Sweller, 1985; Sweller & Levine, 1982; Sweller, Mawer, & Ward, 1983). A body of research that examines how to teach problem solving by reducing cognitive load and supporting problem schema development focuses on worked examples.

In several different domains of problem solving research, the process of comparing "worked examples" (i.e., problems with their solutions already worked out) may be important in the abstractions of a problem schema (Gick, 1986). Van Merriënboer et al. (2002) argued, when solving a problem in a complex learning environment, the learners are required to integrate knowledge, skills, and attitudes, and coordinate qualitatively different constituent skills. Worked examples, because of their descriptive nature, assist learners with the identification of task components and solution steps. When studying worked examples, learners may attend only to the surface features of a problem and not to the underlying principles that govern the operation of a system (Darabi, Nelson, & Palanki, 2007), which will reduce cognitive load in working memory.

The use of worked examples in problem solving has two advantages. Greeno (1980a) points out that the domain-specific problem solving strategies (equivalent to schemas in the present context) are not explicitly taught in a normal situation. They must be induced and this is not usually as efficient as step-by-step guidance in solution methods. Worked examples involve step-by-step guidance and this may provide one reason to expect the use of worked examples to be superior to other problem solving strategies. Besides, detailed worked examples do not require the use of conventional problem solving search strategies. Studying a worked example may directly process the relation between given problem states and the moves required to transform these states into desired alternative states. It is expected that schemas can be acquired more directly by a worked example approach as opposed to a conventional, goal-directed problem solving search approach (Sweller, & Cooper, 1985).

There is a four-stage model using worked examples in problem solving based on the well-known ACT-R framework (Anderson, Fincham, & Douglass, 1997). In the model, learners who are in the first stage of skill acquisition solve problems by analogy; they use known examples of problems, and try to relate those problems to the new problem to be solved. At the second stage, learners have developed abstract declarative rules or schemas, which guide them in future problem solving. At the third stage, with sufficient practice, the schemas become proceduralised, leading to the fourth stage of expertise where automatic schemas and analogical reasoning in a large pool of examples are combined to successfully solve a variety of problem types. Empirical evidence has shown that learning with worked examples is most important during initial skill acquisition stages in well-structured domains such as physics, programming, and mathematics (Van-Lehn, 1996).

There has been great use of web-based learning environments related to worked examples. Most of the research on worked examples in web-based learning environments provides evidence that the instructional method of worked examples is efficient in well-structured domains such as Science. Research has shown the effects of worked examples on knowledge sharing processes in web-based learning (Crippen and Earl 2007; Gerjets et al. 2008; Gerjets et al. 2006; Kim 2005; Paas and van Merri/nboer 1994; Schworm and Renkel 2006).

3) Worked Examples and Prior Knowledge

Research has convincingly shown that studying examples is more effective for acquiring new knowledge and facilitating problem solving within the limitations of cognitive resources. However, worked examples do not work all the time. Research on the expertise-reversal effect has shown that a learner's prior knowledge determines the effectiveness of worked examples (van Gog et al., 2006). Kalyuga et al. (2001) supposed that ''Expertise reversal effects'' may take place in the learning of worked examples.

Besides, in recent studies, some researchers have found that the effectiveness of instructional materials is dependent on the expertise of the learners. Some correlation is found between the prior knowledge levels of learners and the amount of information included in instruction. As worked examples are not always beneficial for all learners, a learner's cognitive load should be considered (Ward &

Sweller, 1990; Kalyuga et al., 2001). In an elementary school experiment, Kim (2005) also found that worked examples are not effective for learners who have already formed a partial schema of target cognitive knowledge. As a result, when connected with the different presentation formats of worked examples, there is a need to examine the different formats' impact on the different prior knowledge levels of learners. There is a relationship between prior knowledge levels of learners and the ways of information included in instruction.

In a recent study, van Gog et al (2004) argued that the sequencing of instructional information plays an important role in schema development and activation in novice learners. They also examined how variations in the sequencing of worked example conditions can affect learning efficiency (van Gog et al., 2006). The study found that as expertise is gained during learning, the process-oriented worked examples would hinder learning, though initially foster learning. As a result, there is a need to further examine the effect of worked example strategies and learners' prior levels of performance, mental effort, and understanding.

In the preceding section, process-oriented and product-oriented worked examples are mentioned to be examined in this study. Studying the process-oriented worked examples is supposed to stimulate learners' construction of cognitive schema during learning, which would subsequently decrease more extraneous load in working memory than studying product-oriented worked examples for problem solving. However, the result is remained to be examined, as the prior knowledge levels may become a mediating fact to affect the results.

The main difference between process-oriented and product-oriented worked example is process-oriented worked examples not only include principled information but also strategic information (heuristic and systematic approaches to problem solving). Some researchers have tried to study the two different formats of worked examples. A recent experiment on the effects of process-oriented worked examples in the domain of electrical circuits troubleshooting was done, but it only focused on the ability of transfer affected by process-oriented worked examples (van Gog et al., 2006). Before learners try to study the material, they have different levels of prior knowledge, that the two worked example formats would have an effect on levels of prior knowledge is worthy of studying.

As a result, the present study is aimed at investigating to find a possible explanation for this hypothesis, one that might apply to worked examples instruction, that is, the occurrence of an “expertise-reversal effect” which is influenced by learners’ prior knowledge. Instructional formats that work well for learners with little or no prior knowledge may be less effective or ineffective for learners with more knowledge. Kalyuga et al. (2001) says that worked examples are effective for low prior knowledge learners, but not for high prior knowledge learners. ‘‘Expertise reversal effects’’ take place (Kalyuga et al. 2003). However, in that study the worked examples were not distinguished by different presentation types. As a result, it is necessary to explore different presentations types of worked examples while considering expertise-reversal effects.

Consequently, it has been argued that in initial training learners may benefit from studying process-oriented worked examples that not only show the solution steps, but also expressly state the rationale behind those steps (van Gog et al., 2004). However, the product-oriented worked examples typically seem to exhibit a lack of principled and strategic knowledge underlying the solution procedure. As a result, the performance of learning with a low prior level of knowledge may be affected by this kind of presentation.

5. Summary

Cognitive load research has demonstrated the effectiveness of worked examples for problem solving in improving learning and transfer performance and reducing learners' extraneous cognitive load in more than two decades (Paas & van Merriënboer, 1994; Clark, Nguyen, & Sweller, 2006). In some recent studies, the interest has shifted to examining instructional techniques.

Consequently, the present study extended the research of van Gog and colleagues (2004; 2006; 2008) on the effectiveness of process-oriented and product-oriented worked examples on learning and transfer in web-based problem solving learning environment. In addition, since the inherent complexity or intrinsic load of a task has been shown to be influenced by prior knowledge (Kalyuga et al., 2003; Pollock et al., 2002), the individual prior knowledge level of learners was considered. The effectiveness of process-oriented or product-oriented worked example strategy of instruction was examined by learning achievements in this study. And the learning outcome was expected to be mediated by the learners' prior knowledge. This study compared the effects of a process-oriented and product-oriented worked example mediated by learner's prior knowledge on learning achievement and cognitive load. The results of this study were intended to extend the knowledge of worked examples design to better inform designers and instructors of how to use worked example strategies to create an effective instructional environment.

III. METHOD

This chapter describes the methodology employed to investigate the effects of different formats of worked example instructional strategies on mental effort and learning achievements for problem solving skills in web-based learning. The approaches that were used to compare the effects of process-oriented and product-oriented worked example strategies on learning performance and mental effort will be described. The following components will be addressed in this section: (1) Participants; (2) Experimental Design; (3) Research Procedure; (4) Materials and Instruments.

1. Participants

The participants in this study consisted of first-year students with mathematic in their curriculum of S middle school in China. The reasons for choosing these learners are as follows. First, the first-year middle school students have enough self-directed problem solving ability in web-based learning environment. Second, the mathematic curriculum of first-year middle school can provide problem solving materials for applying worked examples instructional strategy. Since worked example is useful for complex problem solving, low grades of mathematic cannot provide the comparable teaching material.

The total population was 152 and the students were selected from four existing classes of the same school. The study took place over the course of regularly scheduled period in their classrooms. Since every student had a computer in the classroom, they could finish the instruction online by themselves. According to their groups, the 152 students were divided into 4 groups. Table III-1 shows the number of participants assigned to each instructional condition. The number of participants assigned to each instructional condition was relatively equal.

<Table III-1> Assignment to Instructional Conditions

	Group	Number	Number of Group
Experimental Group	Process-oriented	76	2
	Product-oriented	76	2
	Total	152	4

2. Experiment Design

1) Variables

Independent Variables

The two independent variables used in this study were two types of worked example instructional strategies and prior knowledge levels. The two types of instructional strategies included process-oriented worked example instruction and product-oriented worked example instruction. At the same time, the prior knowledge levels included high prior knowledge level and low prior knowledge level.

Dependent variables

The dependent variables used in this study were participants' academic achievements and mental effort. The performance test and mental effort test were used to see whether there were initial differences about two types of worked example instruction strategies that might affect the result of this study.

2) Group Design

In this study, two instructional conditions were created based on the two types of worked example strategy (process-oriented and product-oriented problem solving). Participants were randomly assigned to the two conditions: process-oriented worked example instructional strategy and product-oriented worked example instructional strategy. Table III-2 shows the design of the experiment to each instructional condition.

<Table III-2> Design of the Experiment

Group	Pre-test	Experimental Treatment	Post-test
G1	O1	X1	O3
G2	O1	X2	O3
G3	O1	X1	O3
G4	O1	X2	O3

O1: Pre-test (Prior knowledge test)

G1, G3: Groups provided with process-oriented worked example instructional strategy

G2, G4: Groups provided with product-oriented worked example instructional strategy

X1: Process-oriented Worked Examples Instructional Strategy

X2: Product-oriented Worked Examples Instructional Strategy

O3: Post-test: (1) Learning Achievement Test, (2) Mental effort Test

In this study, since the prior knowledge level is a dependent variable, participants were divided into two groups based on their scores from a pre-test (prior knowledge level test): high prior knowledge levels and low prior knowledge levels. A 2 x 2 subject factorial design was applied with two presentation formats of worked examples (process-oriented & product-oriented) and prior knowledge (high

/ low). Table III-3 shows the design of experiment. The number of participants assigned to each instructional condition was relatively equal.

<Table III-3> Design of the Experimental Group

Instructional Strategy / Prior Knowledge Level	Process-Oriented	Product-Oriented	Total
High Prior Knowledge (HP) 40% in the top of group	28	33	61
Low Prior Knowledge (LP) 40% in the bottom of group	33	30	63
Total	61	63	124

3) Learning Environment

This study was held among middle school students. In many schools lectures are taught in the classrooms which can hold about 40 students in China. In order to realize the web-based learning, the instruction was designed to happen in computer classrooms. As a result, the instruction was conducted in science classroom where all participants could use individual computer terminals. The teacher could watch every student's learning progress through the monitor computer which was set in front of the classroom.

3. Procedure

The procedure for the present study involved completion of three phases: (1) preparation, (2) implementation, and (3) data collection and processing

Phase I: Preparation for Experiment

Since the instruction was planned to be implemented with the proceeding teaching program in the first two weeks of March in the spring semester, a deep study was done with the mathematic curriculum of first-year middle school students before the instructional programmed was developed. With the assist of three mathematic teachers who had several years teaching experiences as subject matter experts, the teaching content about parallel lines was selected and designed with three complicated problem solving questions. The web-based process-oriented worked example program and product-oriented worked example program were designed and developed two weeks before the implementation. The pretest and post-test were also made with the help of mathematic teachers who directly taught the participants at that time. The mental effort questionnaire was also developed.

To obtain more reliable and validate results, in this study, after all the instruments were developed, the assessment of feasibility was done by a PH.D. candidate in educational technology and studying as a researcher in academic institutions, and three subject matter experts through interview. Besides, an expert who had experiences in years of instructional design participated. The expert was PH.D.in educational technology who working in academic institutions. Considering their occupations, careers, and educational backgrounds, they were appropriate for participating in this study. By co-working with them, the instructional program and instruments can be validated on a proper level.

At the same time, before the implementation, the program was pre-implemented on 5 students who were first year students in middle school. According to the pre-implementation, some revisions were done which would make participants understand the program and tests more easily.

Phase II: Implementation of Experiment

In this study, experiment was implemented from February 20th to March 9th. It lasted about three weeks. The spring semester started in February 13th. The reason why the experiment was implemented two weeks later was that students would have already learned some basic knowledge and could solve more complicated problems during the experiments. Four classes of students were selected as the participants.

From February 20th to 24th, the prior knowledge level test (pretest) was taken. In the following week, learners were guided and trained how to learn by themselves in a web-based learning environment. Concerning the prior knowledge, participants were divided into high knowledge level and low knowledge level groups based on the pretest. High knowledge level learners were in the top 40%, low knowledge level learners were in the bottom 40% of the total participants, and the learners in the middle 20% were excluded because we could not call these learners as high knowledge level or low knowledge level; actually, the scores of these 20% learners seemed very similar so that they were excluded.

From March 5th to 9th, the instruction was given to the participants. All of them had never studied the problems previously and had already learned the basic conceptions about parallel lines. For each participant, achievement post-test and mental effort test were taken after web-based learning on worked examples.

Phase III: Data Collection and Processing

When the experiment was finished, test and questionnaire papers were collected. There were 155 participants in total. Excluding three students who did not take all the tests through the three weeks, 152 participants' scores were identified to be valid. To obtain more reliable and validate results, the achievement scores were examined by two experienced mathematics teachers. The mental effort test was also measured according to 9-point scale self-reporting rating scale developed by Paas (1992). The outline of the research procedure and details are diagrammed in Figure III-1.

Figure III-1 The outline of the research procedure and details.

Phase	Research Activity
Defining Research Problem	Proposing the Problem Statement & Research Questions • Analyses of the Purpose of the Study • Defining Research Questions
Exploration	Data Collection • Review of Literature • Identifying Participants • Identifying and Analyzing Materials • Development of Assessment
Development	Preparation for Experiment • Instrument for Pre-test • Design of Web-based Problem Solving Learning Program • Instrument for Mental effort • Instrument for Learning Achievement Implement of Experiment • Implement of Pre-test • Introduction to Web-based Learning Instruction • Implementation of Instruction • Achievement Test • Mental effort Test
Interpretation of Results	Data Collection • Grading Test Scores • Coding Data Analyses

4. Instruments

1) Prior Knowledge Level Test

In this study, a pretest was taken for identifying prior knowledge level test. The prior knowledge level test was a test consisting of 13 questions designed to assess learners' basic knowledge of parallel lines for the present study. After the prior knowledge level test was developed, it was examined by two mathematics teachers. With some feedback and modification, the pretest was taken finally (see Appendix B). In this study, a participant's prior knowledge level was determined by calculating the number of questions answered correctly. According to the results of scores, the homogeneity of variance experimental groups could also be identified.

2) Web-Based Worked Example Learning Program

In this study, the web-based materials consisted of two kinds of materials on parallel lines: process-oriented worked example instruction and product-oriented worked example instruction. The problems showed in the different programs were same but different in the explanations. Before the design of the instruction, an in-depth interview was done with the teachers and participants. The content of educational materials was studied during a long time so that not very difficult or easy content would be selected. In the whole process of designing, all decisions were made with the assistance and feedback of two mathematics teachers to assure the validation.

Analysis of Contents

The web-based learning contents developed by using HTML language, consisted of two formats of worked examples. The worked example instruction was designed with three problem solving questions involving parallel lines. The three questions were selected from a variety of example resources and could be good examples to improve learner's comprehensive problem solving ability.

Web-Based Learning Program

The web-based learning program consisted of two parts: learning guide and learning content. The learning guide page was designed with the learning contents list and objectives. As shown in Figure III-2, in the guide page a learner could get a general idea about what would be learned and choose his type of learning strategy.

Figure III-2 Guide Page of Web-based Learning Program

The process-oriented worked example instruction presented learner with three worked examples and required a completion time of approximately 40 minutes (see Appendix A for the complete packet). As shown in Figure III-3, at first participant was asked to think by themselves about the answers to the problems. Then the answers provided the participant with the necessary procedural steps required to perform the analysis process as well as the underlying principle or the "why" behind the step or "how" the task being performed. Figure III-4 shows a process-oriented worked example. The instruction needed participants to finish the learning by themselves. There was no external assistance all through the instruction.

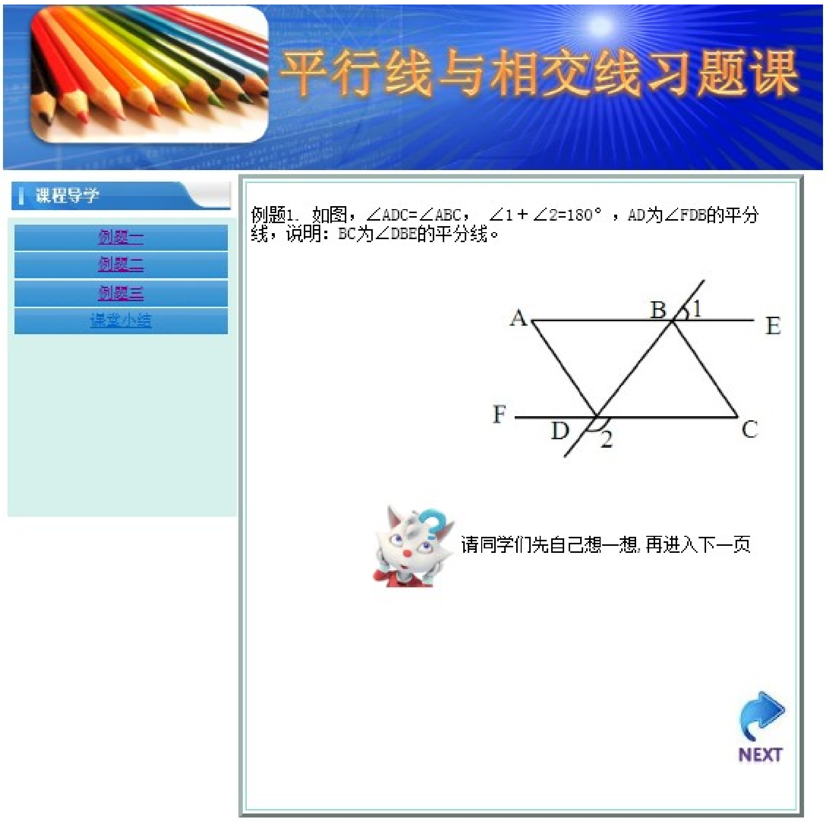


Figure III-3 Problem Statement

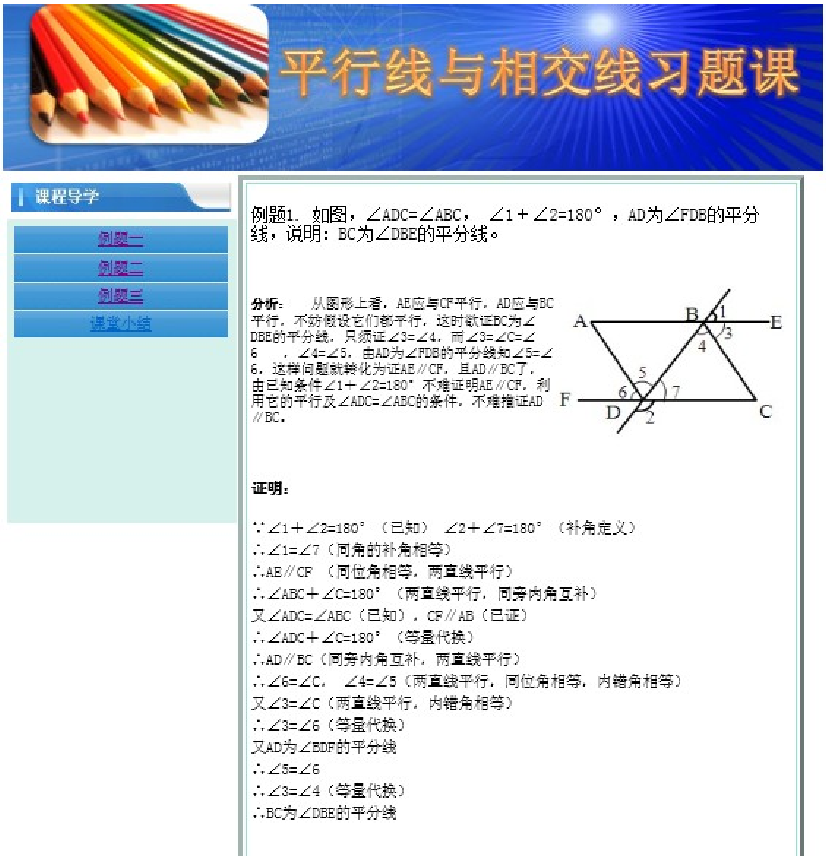


Figure III-4 A process-oriented Worked Example

The practice problems were the same as those provided in product-oriented instruction with a completion time of approximate 40 minutes (see Appendix A for the complete packet). The whole steps were the same with process-oriented instruction. However, in this instruction, the participant was only provided with the necessary procedural steps to solve the problem. Using the same problem statement in the previous examples, Figure III-5 shows the procedural steps provides to a participant in a product-oriented worked example.

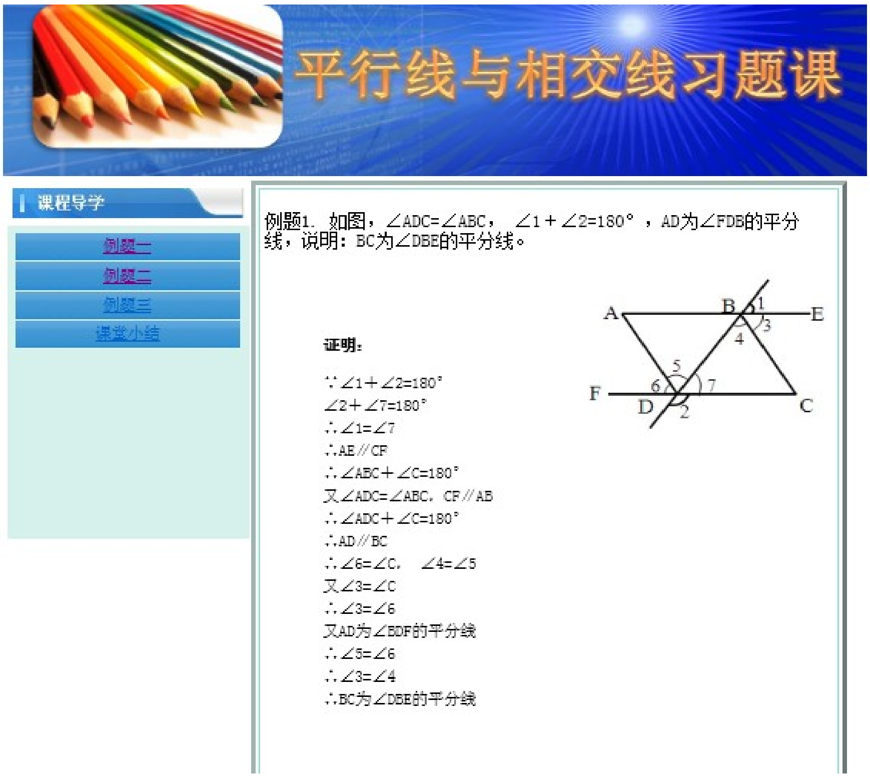


Figure III-5 A product-oriented Worked Example

3) Achievement Test

To measure learning achievements, participants were asked to finish a post-test after the instructional segments were finished. The post-test consisted of 3 problems. Since the three problems showed in the instruction were very typical ones for parallel lines, the post-test items were designed similarly to the example problems showed in the instruction. These 3 items were used to determine performance in the context of this study (see Appendix C for the complete packet).

To get valid achievement measurement, the test was designed with two mathematics teachers who taught the participants directly.

4) Mental Effort Measurement

There are different subjective and objective techniques available for measuring cognitive load (see Paas, Tuovinen, Tabbers, & Van Gerven, 2003). One early attempt to measure cognitive load was made by Sweller (1988) in his study on problem solving. Using an analytical approach, he developed a strategy using secondary task measurement to determine load. Paas (1992) firstly demonstrate the use of a rating scale in the context of cognitive load theory. The scale's reliability and sensitivity (Paas, van Merriënboer, & Adam, 1994) and ease of use have made this scale, and variants of it, the most widespread measure of working memory load within CLT research. Other researchers have demonstrated the scale's reliability, and convergent, construct, and discriminate validity (Gimino, 2000; Paas et al., 1994).

After completing the instructional activity, participants' mental effort was measured by using a 9-point scale self-reporting rating scale developed by Paas (1992). The measurement will be ranged from extremely low mental effort (1 point-

-“very, very low effort”) to extremely high mental effort (9 points—“very, very high effort”) (see Appendix D).

5. Data Analyses

The major purpose of this study was to examine the effects of worked example formats and prior knowledge levels on cognitive load and academic achievement for problem solving skills. To find the results of research questions (see Chapter 2), quantitative data was collected and processed by SPSS windows 18.0.

A T-test was used to compare the effects of two types of instructional strategies with the pretest as covariates to see whether there were initial differences about process-oriented worked example instruction and product-oriented example instruction. Two way analyses of Variance (ANOVA) was used to compare the interactive effects among groups on each dependent variable.

6. Summary

In this chapter, the methodology for the study, the research design and procedure, participants of the study, and instruments for tests were provided. To achieve the purpose of the study, a web-based learning program was designed and an experiment was performed. Data was collected, processed and analyzed by using T-test and Two-way analyses of variance (ANOVA) in SPSS. In the next chapter, the results of the analyzed data will be presented.

IV. RESULTS

The purpose of this study was to identify the effects of worked example formats and prior knowledge levels on cognitive load and academic achievement for problem solving skills. To fulfill these objectives, two formats of worked example instruction were developed. In the first phase, the worked example instruction was identified from the literature review. Then the two formats of worked example instruction were validated by experts and finalized. In the second phase, effects were identified between the process-oriented worked example instruction and product-oriented example instruction with the interference of learners' prior knowledge level. Following a description of the impact of the treatment and a discussion of reliabilities between evaluators, these findings are described according to the three hypotheses:

1) The formats of worked examples (i.e. process-oriented or product-oriented worked examples) have an effect on learners' problem solving achievement in web-based learning environment.
2) There is an interaction effect between different worked example formats (i.e. process-oriented or product-oriented worked examples) and learners' prior knowledge on cognitive load when solving problems in web-based learning environment.

3) There is an interaction effect between different worked example formats (i.e. process-oriented or product-oriented worked examples) and learners' prior knowledge on problem solving achievement in web-based problem solving learning.

The purpose of this chapter is to present the findings of the study. This chapter reports the results from an analysis of data collected during this study. For the purpose of presenting the results, this chapter is divided into four sections.

In this first section, the homogeneity of variance assumption was conducted to establish equivalence of treatment groups, and to determine whether the assumptions or parametric statistics were upheld. An alpha level of .05 was used for all statistical tests.

In the second section, the results of descriptive statistics are summarized. In the third section, the results of primary data analyses of the dependent variables are reported. Hypothesis 1 regarding main effects of worked example formats was tested by T-test. Hypothesis 2 and 3 regarding the interaction effects of the worked example formats and a prior knowledge level were tested based on dependent variables by Two-way analyses of Variance (ANOVA). The results are reported.

1. Preliminary Data Analyses

In this section, the homogeneity of variance assumption was conducted as the foundation for the primary data analyses. Then results of descriptive statistics are summarized.

As shown in Table IV-1, the Levene's test for pre-test was conducted to test the assumption of homogeneity of variance for each dependent variable to determine whether or not the variances in the four groups were equal. The results of the test indicated that the prior performance level was not significantly different across treatment groups.

<Table IV-1> Test of Homogeneity of Variances for Pre-test

Levene Statistic	df1	df2	Sig.
2.233	3	120	.088

Since the major statistical methods for data analyses of this study is ANOVA (for hypothesis 2 and 3), Levene's tests were conducted again for the specific investigation on any variance or correlation differences across the groups. Levene's test of the assumptions of homogeneity of variance for each of the dependent variables resulted in failure to reject decisions for all variables, a result consistent with the assumption that the variances were equal over the groups (see Table IV-2).

<Table IV-2> Levene's Test of Equality of Error Variances

Dependent Variable	F	df1	df2	Sig.
Post-test (interaction effect)	.378	3	120	.769
Mental effort (interaction effect)	.071	3	120	.975

2. Descriptive Statistics

The current study focused on three research hypotheses. The first hypothesis aimed to main effect between process-oriented worked example instruction and product-worked example instruction; while the last two hypotheses aimed to interaction effects of formats of worked example instruction and prior knowledge level on performance and mental effort. Data from the post-test and mental effort measures were analyzed using T-test and Two-way analyses of variance (ANOVA). A significance level of .05 was used for the analyses reported in the present study.

The results of descriptive statistics are summarized as follows: it showed the results of initial descriptive analyses which included the means, standard deviations, minimum, and maximum for dependent variables.

Hypothesis 1: *"The formats of worked examples (i.e. process-oriented or product-oriented worked examples) have an effect on learners' problem solving achievement in web-based learning environment."*

For this hypothesis, it was necessary to identify the effects by considering the prior knowledge level. The mean scores and standard deviations for the post-test are displayed in Table IV-3 by process-oriented worked example instruction versus product-oriented worked example instruction. There are both 76 participants who received process-oriented worked example instruction and product-oriented worked example instruction. By type of process-oriented worked example instruction, the total mean score (43.86) was lower than that of product-oriented worked example instruction (45.29).

<Table IV-3> Descriptive statistics for achievement

Type	M	SD	N
Process-oriented	43.86	23.031	76
Product-oriented	45.29	20.528	76
Total	44.57	21.755	152

Notes:

a. Process-oriented = Process-oriented worked example instruction

b. Product-oriented = Product-oriented worked example instruction

Hypothesis 2: *"There is an interaction effect between different worked example formats (i.e. process-oriented or product-oriented worked examples) and learners' prior knowledge on cognitive load when solving problems in web-based learning environment."*

To measure hypothesis 2, the high 40% level of prior knowledge and low 40% level of prior knowledge participants were selected. The mean scores and standard deviations for mental effort are displayed in Table IV-4 by high prior knowledge level learners versus low prior knowledge level learners. Total mean score for mental effort was 6.10. By type of process-oriented worked example instruction, the total mean score of mental effort (5.85) was lower than that of product-oriented worked example instruction. By levels of prior knowledge control, the total mean score for high prior knowledge level of process-oriented worked example group (6.57) was higher than that of the product-oriented worked example group (6.42). The total mean score for low prior knowledge level of product-oriented worked example group (5.24) was lower than that of the product-oriented worked example group (6.27).

<Table IV-4> Descriptive statistics for mental effort

	Process-oriented worked example			Product-oriented worked example			Total		
	N	M	SD	N	M	SD	N	M	SD
High 40%	28	6.57	1.451	33	6.42	1.733	61	6.49	1.598
Low 40%	33	5.24	1.621	30	6.27	1.507	63	5.73	1.638
Total	61	5.85	1.672	63	5.73	1.638	124	6.10	1.657

Notes:

a. Process-oriented = Process-oriented worked example instruction

b. Product-oriented = Product-oriented worked example instruction

c. High 40% = High prior knowledge level group

d. Low 40% = Low prior knowledge level group

Hypothesis 3: *"There is an interaction effect between different worked example formats (i.e. process-oriented or product-oriented worked examples) and learners' prior knowledge on problem solving achievement in web-based problem solving learning."*

Hypothesis 3 is similar with Hypothesis 2. The mean scores and standard deviations for post-test are shown in Table IV-5 by control of prior knowledge levels. Total mean score for prost-test was 42.74. By type of process-oriented worked example instruction for post-test (41.91) was lower than that of product-oriented worked example instruction (43.55). By levels of prior knowledge control, the total mean score for high prior knowledge level of process-oriented worked example group (58.09) was a litter lower than that of the product-oriented worked example group (58.44). The total mean score for low prior knowledge level of product-oriented worked example group (28.18) was higher than that of the product-oriented worked example group (27.17).

<Table IV-5> Descriptive statistics for post-test

	Process-oriented worked example			Product-oriented worked example			Total		
	N	M	SD	N	M	SD	N	M	SD
High 40%	28	58.09	17.379	33	58.44	15.105	61	58.28	16.051
Low 40%	33	28.18	16.774	30	27.17	17.155	63	27.70	16.826
Total	61	41.91	22.623	63	43.55	22.434	124	42.74	22.450

Notes:

a. Process-oriented = Process-oriented worked example instruction

b. Product-oriented = Product-oriented worked example instruction

c. High 40% = High prior knowledge level group

d. Low 40% = Low prior knowledge level group

3. Tests of Hypotheses

<u>Hypothesis 1</u>: *"The formats of worked examples (i.e. process-oriented or product-oriented worked examples) have an effect on learners' problem solving achievement in web-based learning environment."*

The first hypothesis stated that there might be a significant difference in the achievement of learners in the web-based learning environment. The hypothesis was not supported. The means and standard deviations on the post-test scores by process-oriented worked example instruction were 43.86 (23.031) and 45.29 (20.528) for product-oriented worked example instruction (see Table IV-6). As evidenced by the result, learners who completed the product-oriented worked example instruction had slightly higher scores than learners who completed the process-oriented worked example instruction. However, a t-test indicated no significant difference in the post-test scores of learners in the two different treatment conditions, $t = .405$, $P > .05$ (Table IV-6).

<Table IV-6> T-test for achievement test scores

Experimental Group	N	Mean	t	Sig.(2-tailed)
Process-oriented	76	43.86	.405	.686
Product-oriented	76	45.29		
Total	152	44.57		

Hypothesis 2: *"There is an interaction effect between different worked example formats (i.e. process-oriented or product-oriented worked examples) and learners' prior knowledge on cognitive load when solving problems in web-based learning environment."*

The Hypothesis 2 was to examine the interaction effect of prior knowledge and worked example formats on cognitive load. This hypothesis was supported. The total mean score for high prior knowledge level of process-oriented worked example group (6.57) was higher than that of the product-oriented worked example group (6.42); and the total mean score for low prior knowledge level of product-oriented worked example group (5.24) was lower than that of the product-oriented worked example group (6.27) (see Table IV-4). To examine this hypothesis, a two-way analyses of variance was used for analysis. Data in Table IV-7 showed that interaction effect of worked example formats was significant, F = 4.194, P < .05.

As was examined, the findings indicated that learners with high prior knowledge level presented in process-oriented worked example instruction reported higher mental effort ratings than learners with high prior knowledge presented by product-oriented worked example instruction. And learners with low prior knowledge level presented in process-oriented worked example instruction reported lower mental effort ratings than learners with low prior knowledge presented by product-oriented worked example instruction.

< Table IV-7> Two-way analyses of variance for mental effort

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Prior knowledge level	17.045	1	17.045	6.754	.011
Worked example format	5.933	1	5.933	2.351	.128
Prior knowledge level *Worked example format	10.584	1	10.584	4.194	.043*
Error	302.845	120	2.524		

a. R Squared = .103 (Adjusted R Squared = .081)

* $p < .05$

<u>Hypothesis 3</u>: *"There is an interaction effect between different worked example formats (i.e. process-oriented or product-oriented worked examples) and learners' prior knowledge on problem solving achievement in web-based problem solving learning."*

Hypothesis 3 proposed that there would be a significant interaction between prior knowledge and worked example formats on achievement. Similar to the first hypothesis, the results failed to reject the null hypothesis of no difference. The overall post-test means for high and low prior knowledge level learners with process-oriented worked example instruction were 58.09 and 28.18 respectively; in product-oriented worked example learners were 58.44 and 27.17 (see Table IV-5).

Results (see Table IV-8) show that the significant interaction effect of worked example formats and prior knowledge was not significant, $F = .052$, $P > .05$. This finding indicated that low prior knowledge learners showed no significant differences in neither process-oriented nor product-oriented problem solving conditions.

< Table IV-8> Two-way analyses of variance for achievement

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Prior knowledge level	28869.341	1	28869.341	105.002	.000
Worked example format	3.411	1	3.411	.012	.911
Prior knowledge level *Worked example format	14.376	1	14.376	.052	.820
Error	32992.981	120	274.942		

a. R Squared = .468 (Adjusted R Squared = .454)

V. DISCUSSION

This chapter provides a summary of the results of the study and a discussion to interpret the meaning of the results. Next, the limitations and implications of the study are discussed. Finally, recommendations for future research and a brief conclusion are presented.

1. Summary of Result & Its Interpretation

This study examined the effects of worked example formats (process-oriented or product-oriented) and prior knowledge level on cognitive load and academic achievement for problem solving skills. In the following sub-section, results and their interpretation are presented. Especially, interpretations about the results of the testing of hypothesis 1 (the main comparative effects of the process-oriented worked example and product-oriented worked example), hypothesis 2 (the interaction effect of the worked example and prior knowledge level on mental effort), and hypothesis 3 (the interaction effect of the worked example and prior knowledge level on academic achievement) are presented.

1) The main comparative effects of two worked example formats

The interpretations about the main comparative effects of process-oriented worked example and product-oriented worked example on academic achievement for problem solving skills are presented in the following sections. The effects on achievement were measured by all participants' post-test scores. In the post-test score, the main effect of the worked examples formats was not significant. It means that the process-oriented worked example instruction did not show better results than product-oriented worked example instruction. The additional information provided by process-oriented worked example may have only limited effects on academic achievement. This is contradictory to the hypothesis. In other research the process-oriented worked example also did not enhance learning more than product-oriented worked example (van Gog, T., Paas, F., & van Merriënboer, J. J. G., 2006).

There may be two possible explanations for why the beneficial effects on achievement of process-oriented information added to worked examples were not found. The first possible explanation may be that there was a lack of coherence between the problem solving tasks and post-test questions. In this problem solving training task, the process-oriented and product-oriented worked examples were integrated with the three tasks (see Appendix A). During the instructional activity, participants were asked to finish learning three tasks and then they were required to complete a post-test for performance assessment. The post-test was designed with the teachers who taught the learners directly. The pos-test was designed with three far transfer tasks and each of them was matched with the three tasks provided in the instructional materials. Considering that every participant had learned about parallel lines for one week, the post-test was designed to be gradually more difficult in order to examine learners' achievements for solving mathematics problems. Every participant was given 40 minutes to finish the post-test. However, the post-test seemed a little difficult so that less than half of the participants could not finished the last and most complicated task. It seemed that participants could not apply what they have learned well in the post-test. According to some interviews with the learners, it was found that, the learners might not connect the post-test tasks with the training sections very well. Besides, some of researchers thought that it is not sufficient to provide worked examples alone as an instructional strategy for learning complex skills (Darabi, Nelson, & Palanki, 2007). So, simply having participants learn the complex math tasks by themselves and then solve some far transferring problems may not promote learning efficiently.

Another possible reason may be due to the findings that the design method of process-oriented worked example could not make learners concentrate more on the additional information. The worked examples in this study were designed only with test and diagrams for mathematics problem solving. Although the process-oriented worked examples provided "how" and "why" information for learners, it seems that they did not pay much attention to that information. They might skip or not think of it carefully during the reading, which led to no significant differences for the two formats. Future studies may focus on other design methods of process-oriented worked examples so that the “how” and “why” principles can be emphasized differently. For example, some audio or animation may be considered as an addition, to help learners focus their attention on the additional information.

2) The interaction effect on mental effort

Hypothesis 2 was proposed to identify the interaction effect of worked example and prior knowledge level on mental effort in worked example instruction for problem solving learning skill. It was expected that there would be a significant difference in the mental effort scores of participants with high prior knowledge level and low prior knowledge level. The results clearly confirm the second hypothesis. The previous results have demonstrated that worked examples can limit the amount of mental effort invested in solving a problem (Paas, 1992; Paas & van Merriënboer, 1994). In this study, it further indicated that the mental effort was differently limited according to different worked example formats. For high prior knowledge participants, they showed higher mental effort with process-oriented worked example instruction than product-oriented worked example instruction. However, for low prior knowledge participants, the results were opposite. The process-oriented worked example group of participants seemed to show less mental effort than the product-oriented worked example group.

A possible explanation of this finding is germane load. In instructional procedures, intrinsic cognitive load is considered fixed; the efficiency is mainly affected by extrinsic cognitive load (Ayres, in press; Sweller et al., 1998). Process-oriented worked examples providing with additional information in essence means that more extra information was added to the task. Although details on “why” and “how” information was thought to have been helpful for all the learners in the instruction, it turned out to have added mental effort for high prior knowledge learners. For low prior knowledge learners, the additional processing of the “why” and “how” information led to less mental effort, that is, the process-oriented worked examples did benefit learners with developing schema. However, for high prior knowledge learners, they should have already establish their own schema, the additional information became a redundant mental activity and learning was disrupted. As a result, the high prior knowledge learners who took the product-oriented worked example instruction showed less mental effort. The previous research also has found that the processing and additional information can increase mental load (van Gog et al., 2006).

Another possible reason may be related to the participants’ prior knowledge. That is, the expertise-reversal effect may happen. According to Kalyuga et al. (2003), expertise-reversal effect happened when adding redundant explanatory information for high prior knowledge learners. As has been mentioned before, the participants had learned parallel lines for about one week. It was argued that learners tend to balance cognitive capacity limits by adjusting the level of mental effort exerted on a complex task (Paas et al., 2003). The instructional materials designed in this study involve three complex problem solving tasks. Those high prior knowledge participants might have already formed their own self-explanation for the rational of the tasks. Besides, since the task was not limited to one solving method, the high prior knowledge learners might have thought about their own different way to solve the tasks. As a result, providing the underlying principles and heuristics or the "why" behind the problem solution in the process-oriented worked example instruction may cause learners focus their attention on the redundant information. On the contrary, the product-oriented worked example only provided the key information so that high prior knowledge learners could only concentrate their attention on the necessary key information. For low prior knowledge learners, they lacked the ability, self-explanation and schema construction. The only key information was not enough to help them construct meaningful self-explanation to the tasks. So the additional information provided in process-oriented worked example instruction had a minimal mental effort on low prior knowledge learners. As mentioned in the first chapter, this proved the hypothesis of van Gog (2006) that the adding process information helped impose a germane load for low prior knowledge learners and impose an extraneous load for high prior knowledge learners.

3) The Interaction effect on achievement

In the first hypothesis, the comparative effects were not found between process-oriented worked example and product-oriented worked example. Contrary to expectation, the same results happened in hypothesis 3. There was no significant difference in hypothesis 3. Since the main effects of process-oriented worked example and product-oriented worked example were not significantly different, it was reasonable for that there was no interaction effects when considering the prior knowledge level of learners. As a result, the expertise-reversal effect did not happen in the post-test.

Although it was not statistically different, the post-test scores of high prior knowledge learners did slightly better in product-oriented group than in process-oriented group; while the opposite results were found in the two low prior knowledge groups. This finding did not support van Gog et al.'s (2006) hypotheses.

4) Summary of Interpretation

In comparative effects of the formats of worked example, that data presented suggested that neither process-oriented nor product-oriented worked example led to a better learning and promoting their problem solving skills . There might not be enough coherence between the problem solving tasks and post-test so that the achievements were not tested differently. Besides, the styles of design may be unfamiliar to learners, and may not allow them to focus their attention effectively on the additional contents. According to this result, there were also no significant differences for interaction effects between formats of worked example and prior knowledge level.

However, in the interaction effect test of mental effort tests, the expertise-reversal effects happened. The prior knowledge level and formats of worked example on mental effort was significantly associated.

2. Limitations of the Study

Several limitations of this study must be considered. First, the results of this study were reported based on the findings of only one-time experiment. As a result, it is not easy to say that the results are reliable enough. There was no similar study to this study dealing with role effect of process-oriented and product-oriented worked example intervolving prior knowledge level. The results of this study should be interpreted cautiously.

Second, the participants of this study were all middle school students. The instruction was given in their normal teaching time. According to the teaching schedule of the school, the four groups were assigned to take the instruction in a regular class session of one and half hours in different days. The learners might not have had enough time for training and the post-tests. If possible, a long-term training session should be performed for a deeper study of worked example instructional strategy.

Third, there was a lack of pre-training. Before the instruction was performed, learners were given an explanation by the teacher on how to use the web-based problem learning system. And the participants were asked to finish the instruction in a self-regulated way. Since the self-regulation factors play an important role in the design of instruction, the designers, instructors, and researcher should pay much attention to this (Nelson, 2006). This was the first time for the participants to learn in this self-regulated way. It might be possible that the participants were not aware of how to learn in this manner that would promote learning.

Fourth, the post-test for achievement used an open-answered style. Participants could use not only one way to solve the problems for the tasks. So the assessments could be very general, making it hard to have a unified standard for scores.

Fifth，the questionnaires for mental effort lacked an adequate number of questions. The 9-point scale self-reporting rating scale developed by Paas (1992) was adopted in this study. There was only one question developed by Paas for learners; so the answers were not enough to obtain learners’ real thinking about the mental effort.

Sixth, both the process-oriented and product-oriented worked examples were designed only in test. The additional principal information was not emphasized much for the learners. They might not have been able to focus their attention to the information.

Finally，the results of this study were mainly based on quantitative data. If interviews could be done to collect participants' actual and in-depth perception, the results might be more reliable. Learners' post-tests to the questions were very general and did not show any kind of significant difference between conditions.

3. Implications for Instructional Design

This study examined the different effects of process-oriented and product-oriented worked example as an instructional strategy for problem solving skills. The findings of this study may suggest instructional implications for those who want to apply the idea of worked examples into instruction. This study has the significance to support cognitive load theory and expertise reversal effect on the theoretical side. It will contribute practical implication to the instructional strategies with considerations of learners' prior knowledge level when designing instruction for problem solving.

First, the components of worked examples were categorized and their main effects and interaction effects were examined in this study. It may enable researchers and/or practitioners to review the comparative effects of the two formats of worked example and prior knowledge level on achievement and mental effort. These reviews will be helpful for them to design proper instruction when using worked example strategy.

Second, this study tried to examine the effects of worked example formats by considering learners' prior knowledge level. It is argued that it is important to supply supportive information for novices so that they would be aided for better developing relevant schemas and capacities (van Gog et al., 2004). In this study, providing additional information for low prior knowledge learners did not show better results on achievements. However, the results showed that the process-oriented worked example helped to decrease the mental effort for low prior knowledge learners; and the product-oriented worked examples turned out to be better for high prior knowledge learners. In problem solving, especially for complex tasks, it is easily for learners to form high intrinsic load. Adding or reducing the amount of information is considering importantly (Clark, R. C., Nguyen, F., & Sweller, J., 2005) when the high or low prior knowledge learners are involved in the instruction.

Third, the prior knowledge level was identified to have a great role for problem solving when using worked example instructional strategy. It can be concluded that worked example needs to be classified and be differently provided to learners dependent on their own prior knowledge level. It would be meaningful for doing some research with consideration of learning procedure.

4. Future Research

The results of this study suggest several directions for future research. First, the future study should investigate the effects of the present worked example formats by incorporating learners’ prior knowledge level and design principles than those employed in this study and provide empirical evidence in various instructional situations.

Second, in-depth investigations on the effects of two types of worked example formats on each mental effort and achievement are recommended. Although this study presented the effects of process-oriented and product-oriented worked examples on achievement and mental effort, it did not provide in-depth investigation on other effects, such as attitude, satisfactory and etc.

Third, similar studies should be conducted to verify the findings of this study. The worked examples were designed only in well-structured web-based learning environment for problem solving and were for the subject of middle school mathematics. It is necessary to develop the results of the present study in various subjects, with different learners and in ill-structured learning environment. The various design styles of process-oriented worked examples (e.g. including radio or animation) which can concentrate learner’s attention on the additional information are recommended.

Fourth, the effects process-oriented and product-oriented worked examples were only examined independently. According to learners' prior knowledge level, the future research can do more research on the sequence of organizing the contents. It is necessary to examine the most effective way of using process-oriented and product-oriented worked examples in the sequencing strategy for learners.

Finally, it is recommended that a duplicated study is conducted by different data collecting methods. In this study, the researcher mainly used the quantitative data collection method for each dependent variable. More qualitative data is recommended for greater-depth research.

5. Conclusion

The present study attempted to explore the effects of process-oriented and product-oriented worked examples and prior knowledge level on mental effort and academic achievement for problem solving skills in a web-based learning environment. Based on the present findings, the researcher can conclude the following:

In main effects of the two formats of worked examples, the data failed to support the prediction that the process-oriented worked example could lead to a better academic achievement than product-oriented worked example could.

However, in the interaction effects of achievements, although the results showed no significant differences, a review of mean achievement showed a slightly better result for high prior knowledge learners who studied the product-oriented worked example than the learners who studied process-oriented worked examples. On the contrary, in the low prior knowledge groups, the mean of achievement showed a slightly better result for learners who studied process-oriented worked examples than the learners who studied product-oriented worked examples. In the interaction effects of worked example formats and prior knowledge level, the data indicated that the process-oriented worked example led a less mental effort than the product-oriented worked example did for low prior knowledge learners; while for high prior knowledge learners, the product-oriented group of learners showed less mental effort that the process-oriented group. The results may due to the expert reversal effect. In other words, the prior knowledge level plays an important role when using worked example as an instructional strategy. Especially for novice learners, it seems promising to use additional process information that can lead to a better performance and less mental effort.

The study provided useful information on how worked example formats could be effectively utilized in instruction. Also, the study supported the cognitive load theory. Due to the lack of fully randomized design and the short treatment time, the results and interpretation might be exploratory and tentative. Therefore, some future studies that can verify the results are recommended.

REFERENCES

Adelskold, G, Alklett, K, Axelsson R and Blomgren, G (1999) Problem-based distance learning of energy issues via computer network, *Distance Education*, **20**, 1, 129–43.

Anderson, J.R. *Cognitive Psychology and Its Implications*. New York: Free-man, 1980.

Anderson, J. R., Fincham, J. M., & Douglass, S. (1997). The role of examples and rules in the acquisition of a cognitive skill. Journal of Experimental Psychology: Learning, Memory, and Cognition, 23, 932e945.

Ashmore, A.D., Frazer, M.J. & Cassey, R.J. (1979). Problem-solving and problem-solving networks in chemistry. *Journal of Chemical Education*, *56*, 377–379.

Atkinson, R., & Shiffrin, R. (1968). Human memory: A proposed system and its control processes. In K Spence & J Spence (Eds.). *The psychology of learning and motivation: Advances in research and theory* (Vol. 2). New York: Academic Press.

Ayres, P. (in press). Using subjective measures to detect variations of intrinsic load within problems. Learning and Instruction.

Baddeley, A. (1992). Working memory. Science, 255, 556e559.

Baddeley, A. (1993). Working memory and conscious awareness. In A. F. Collins, S. E. Gathercole, M. A. Conway, & P. E. Morris (Eds.), Theories of Memory (pp. 11-28). Hillsdale: Lawrence Erlbaum.

Becker C, Schätzl M, Feist H et al. (1999) Assessment of the effective doese for routine protocols in conventional CT, electron beam CT and coronary angiography. Rofo Fortschr Geb Röntgenstr Neuen Bildgeb Verfahr 170:90–104 [in German]

Bonk, C. J., & Reynolds, T. H. (1997). Learner-centered Web instruction for higher-order thinking, teamwork, and apprenticeship. *Web-based instruction*, 167-178. Britton, B. K., & Tesser, A. (1982). Effects of prior knowledge on use of cognitive capacity in three complex cognitive tasks. *Journal of Verbal Learning and Verbal Behavior, 21*(4), 421-436.

Britton, B. K., & Tesser, A. (1982). Effects of prior knowledge on use of cognitive capacity in three complex cognitive tasks. *Journal of Verbal Learning and Verbal Behavior, 21*(4), 421-436.

Bruggen, J. M., Kirschner, P. A., & Jochems, W. (2002). External Representation of Argumentation in CSCL and the Management of Cognitive Load. *Learning and Instruction, 12*(1), 121-138.

Brunken, R., Plass, J., & Leutner, D. (2003). Direct measurement of cognitive load in multimedia learning. *Educational Psychologist, 38*(1), 53-61.

Callison, D. (1998). Schema and Problem-Solving. *School Library Media Activities Monthly, 14*(9), 43-45. Carrol, W. M. (1994). Using worked examples an instructional support in the algebra classroom. Journal of Educational Psychology, 86(3), 360–367.

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. Cognition and Instruction, 8, 293e332.

Chi, M. T. H., & Glaser, R. (1985). *Problem-solving ability*: Learning Research and Development Center, University of Pittsburgh.

Clark, R. C., Nguyen, F., & Sweller, J. (2005). *Efficiency in learning: Evidence-based guidelines to manage cognitive load.* San Diego, CA: Pfeiffer.

Clark, R. C., Nguyen, F., & Sweller, J. (2006). Efficiency in learning. *Identity, 2011*, 07-26.

Combes, B., & Valli, R. (2007). The future of learning objects in educational settings. In K. Harman & A. Koohang (Eds.), *Learning objects: Applications, implications, & future directions* (pp. 423-461). Santa Rosa, CA: Informing Science Press.

Cooper, G., & Sweller, J. (1987). Effect of schema acquisition and rule automation on mathematical problem-solving transfer. Journal of Educational Psychology, 79(4), 347–362.

Cooper, G. (1998). Research into Cognitive Load Theory and Instructiona l Design at UNSW, http://www.arts.unsw.edu.au/education/CLT_NET_Aug_97.HTML.

Crippen, K. J., & Earl, B. L. (2007). The impact of web-based worked examples and self-explanation on performance, problem solving, and self-efficacy. Computers & Education, 49, 809–821.

Darabi, A. A., Nelson, D. W., & Palanki, S. (2007). Acquisition of troubleshooting skills in a computer simulation: Worked example vs. conventional problem solving instructional strategies. *Computers in Human Behavior, 23*(4), 1809-1819. doi: 10.1016/j.chb.2005.11.00

Darabi, A., Nelson, D., Meeker, R., Liang, X., & Boulware, W. (2010). Effect of worked examples on mental model progression in a computer-based simulation learning environment. *Journal of Computing in Higher Education, 22*(2), 135-147. doi: 10.1007/s12528-010-9033-4

D'Zurilla, T. J., & Goldfried, M. R. (1971). Problem solving and behavior modification. *Journal of abnormal psychology, 78*(1), 107.

Eveland, W. P., Jr., & Sharon, D. (2000). Examining information processing on the World Wide Web using think aloud protocols. *Media Psychology, 2*, 219-244.

Feinberg, S., & Murphy, M. (2000). *Applying cognitive load theory to the design of web-based instruction*.

Fishbein, H. D., Eckart, T., Lauver, E., Van Leeuwen, R., & Langmeyer, D. (1990). Learners' questions and comprehension in a tutoring setting. *Journal of Educational Psychology, 82*(1), 163.

Gagne, R. M. 1977, ***The Conditions of Learning*** **(Holt, Rinehart and Winston, New York, NY).**

Gagne, R.M. (1985). *The condition of learning* (4th ed.). New York: Holt, Rinehart, and Winston.

Gagne, R.M. (1987). (Ed.) *Instructional technology: Foundations.* Hillsdale, NJ: Lawrence Erlbaum.

Gerjets, P., & Scheiter, K. (2003). Goal configurations and processing strategies as moderators between instructional design and cognitive load: Evidence from hypertext-based instruction. *Educational Psychologist, 38*(1), 33-41.

Gerjets, P., Scheiter, K., & Catrambone, R. (2006). Can learning molar and modular worked examples be enhanced by instructional explanations and prompting self-explanations? Learning and Instruction, 16, 104–121.

Gerjets, P., Scheiter, K., & Schuh, J. (2008). Information comparisons in example-based hypermedia environments: Supporting learners with processing prompts and interactive comparison tool. Educational Technology Research and Development, 56, 73–92.

Ge, X. (2001). *Scaffolding students' problem-solving processes on an ill-structured task using question prompts and peer interactions*. Unpublished doctoral dissertation, Pennsylvania State University, University Park, PA.

Gick, M. L., & Holyoak, K. J. (1983). Schema induction and analogical transfer. ***Cognitive P S YC~O~1O5,~*** 1***Y***-3***,***8 .

Gick, M. L. (1986). Problem-solving strategies. *Educational Psychologist, 21*(1-2), 99-120.

Greeno, J. (1977). Process of understanding in problem solving. InN. J. Castellan, D. B. Pisoni, & G. R.

Greeno, J. (1978). Natures of problem-solving abilities. In W. Estes (Ed.), *Handbook of learning and cognitiveprocesses* (pp. 239-270). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Greeno, J. (1980). Some examples of cognitive task analysis with instructional implications. In R. Snow, P. Federico, & W. Montague (Eds.), ***Aptitude, learning and instruction, Vol. 2: Cognitive process analyses of learning and problem solving*** (pp. ***1-21).*** Hillsdale, NJ: Lawrence Erlbaum Associates.

Gunawardena, C N and Zittle, F J (1997) Social presence as a predictor of satisfaction within a computer-mediated conferencing environment, *American Journal of Distance Education*, **11**, 3, 8–26.

Harter, S. P. (1986). *Online information retrieval: Concepts, principles and techniques*. Orlando, FL: Academic Press.

Haury, D.L., & Milbourne, L.A. (1999). Using the internet to enrich science teaching and learning. (ERIC Document No. ED433218)

Hoogveld, A., Paas, F., & Jochems, W. (2005). Training higher education teachers for instructional design competency-base education: Product-oriented versus worked examples. Teaching and Teacher Education, 21(3), 287–297.

Huitt, W. (1992). Problem solving and decision making: Consideration of individual differences using the Myers-Briggs Type Indicator. *Journal of Psychological type, 24*(0), 33-44.

John, S. Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*(2), 257-285. doi: 10.1016/0364-0213(88)90023-7

Jonassen, D. H., & Henning, P. (1996). *Mental models: Knowledge in the head and knowledge in the world*.

Jonassen, D. (2003). Using cognitive tools to represent problems. *Journal of Research on Technology in Education, 35*(3), 362-381Jonassen, D. H. (2004). *Learning to solve problems: An instructional design guide* (Vol. 3): Pfeiffer & Co.

Jonassen, D. H., & Gilmore, E. R. (2005). Learning to solve problems. *Performance Improvement, 44*(9), 45-47.

Joung, S. (2006). The effects of product-oriented whole-task approach on problem solving, cognitive load, and satisfaction. Journal of Educational Technology in Korea, 22(1), 35–55.

Jung, I., Choi, S., Lim, C., & Leem, J. (2002). Effects of different types of interaction on learning achievement, satisfaction and participation in web-based instruction. *Innovations in Education and Teaching International, 39*(2), 153–162.

Kalyuga, S., Chandler, P., Tuovinen, J., & Sweller, J. (2001). When problem solving is superior to studying worked examples. Journal of Educational Psychology, 93(3), 579–588.

Kalyuga, S., Ayres, P., Chandler, P., & Sweller, J. (2003). The expertise reversal effect. *Educational Psychologist, 38*(1), 23-31.

Kanuka, H and Anderson, T (1998) Online social interchange, discord, and knowledge construction, *Journal of Distance Education*, **13**, 1, 57–74.

Keller, J. M., & Suzuki, K. (1988). Use of the ARCS Motivation Model in Courseware Design. In D. H. Jonassen (Ed.), Instructional Designs for Microcomputer Courseware. Hillsdale, NJ: Lawrence Erlbaum.

Khan, B. H. (1997). *Web-based instruction*: Educational Technology Pubns.

Kim, K. (2005). Effect of practice problem on cognitive skill acquisition in multimedia-based instruction. The Journal of Educational Information and Media, 21(3), 33–62.

Kramers-Pals, H. & Pilot, A. (1988). Solving quantitative problems: Guidelines for teaching derived from research. *International Journal of Science Education*, *10*, 511–521.

Kujawa, S., & Huske, L. (1995). The strategic teaching and reading project guidebook (Rev. ed.). *Oak Brook, IL: North Central Regional Educational Laboratory.(accessed November 15, 2003).*

Larkin, J., McDermott, J., Simon, D. P., & Simon, H. A. (1980). Expert and novice performance in solving physics problems. *Science, 208*(4450), 1335.

Lim, C. (1997). The specification and possibilities of problem-solving scenario as an instructional and learning environment design model. Journal of Educational

Technology, 13(1), 59-80. [임철일(1997). Problem-Solving Scenario 교수학습환경 설계 모형의 특정성과 가능성. **교육공학연구**, 13(1), 59-80.]

Lucking, R., & Manning, M.L. (1996). Instruction for low-achieving young adolescents: Addressing the challenge of a generation imperiled. *Preventing School Failure, 40*(2), 82–87.

Marchionini, G. (1988). Hypermedia and learning: Freedom and chaos. *Educational Technology*, 8-12.

Mayer, R. (1983). *Thinking, problem solving, cognition.* New York: Freeman.

Mayer, R., & Chandler, P. (2001). When Learning Is Just a Click Away: Does Simple User Interaction Foster Deeper Understanding of Multimedia Messages? *Journal of Educational Psychology, 93*(2), 390-397.

McLoughlin, C., & Luca, J. (2002). A learner-centred approach to developing team skills through web-based learning and assessment. *British Journal of Educational Technology, 33,* 571–582.

Miller,G.A. (1956).Themagical number seven, plus or minus two: some limits on our capacity to process information. PsychologicalReview, 63, 81e97.

Moreno, R. (2006). When worked examples don't work: Is cognitive load theory at an Impasse? *Learning and Instruction, 16*(2), 170.

Morrison, G. R., & Anglin, G. J. (2005). Research on cognitive load theory: Application to e-Learning. *Educational Technology, Research and Development*, *53,* 94-105.

Mwangi, W., & Sweller, J. (1998). Learning to solve compare word problems: The effect of example format and generating self-explanations. Cognition and Instruction, 16, 173e199.

Nelson, D. W. (2006). Effects of practice sequence variations on the transfer of complex cognitive skills practiced in computer-based instruction. *Dissertation Abstracts International, 64* (04), 115. (UMI No. 3216525)

Newell, A., & Simon, H. A. (1972). *Human problem solving*: Prentice-Hall Englewood Cliffs, NJ.

Niederhauser, D. S., Reynolds, R. E., Salmen, D. J., & Skolmoski, P. (2000). The influence of cognitive load on learning from hypertext. *Journal of Educational Computing Research, 23*(3), 237-255.

Nielsen, J. (1990). *Hypertext and hypermedia*. Boston: Academic Press.

Owen, E., & Sweller, J. (1985). What do students learn while solving mathematics problems? ***Journal of Educationa1 P sychology, 77,*** 272-284.

Paas, F. G. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach. *Journal of Educational Psychology, 84*(4), 429-434.

Paas, F., & van Merriënboer, J. J. G. (1993). The efficiency of instructional conditions: An approach to combine mental-effort and performance measures. *Human Factors, 35*, 737-743.

Paas, F., & van Merriënboer, J. J., & Adam, J. (1994). Measurement of cognitive load in instructional research. *Perceptual and Motor Skills, 79*, 419–430.

Paas, F., & van Merriënboer, J. J. G. (1994). Variability of worked examples and transfer of geometrical problem solving skill a cognitive load approach. Journal of Educational Psychology, 86(1), 122–133.

Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational Psychologist, 38*(1), 1-4.

Paas, F., & van Gog, T. (2006). Optimising worked-example instruction: Different ways to increase germane cognitive load. Learning and Instruction, 16, 87e91.

Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning and Instruction, 12*(1), 61-86.

Polya, G. (1957). *How to solve it: A new aspect of mithematical method.* Princeton, *NJ:* Princeton University Press.

Polya, *G.* (1977). *Mathematical methods in science.* Washington: The Mathematical Association of America.

Polya, G. (1957). *How to solve it: A new aspect of mithematical method.* Princeton, *NJ:* Princeton University Press.

Potts (Eds.), ***Cognitive theory*** (Vol. 2, pp. 43-83). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Reisslein, J., Atkinson, R., Seeling, P., & Reisslein, M. (2006). Encountering the expertise reversal effect with a computer-based environment on electrical circuit analysis. Learning and Instruction, 16, 92e103.

Relan, A., & Gillani, B. B. (1997). Web-based instruction and the traditional classroom: Similarities and differences. *Web-based instruction*, 41-46.

Renkl, A., Stark, R., Gruber, H., & Mandl, H. (1998). Learning from worked-out examples: The effects of example variability and elicited selfexplanations. Contemporary Educational Psychology, 23, 90e108.

Richard, M. (1997). Selected attitudinal factors related to students' success in high school. *Alberta Journal of Educational Research, 43*(2–3), 165–168.

Seng, L., & Mohamad, F.S. (2002). Online learning: Is it meant for science courses? *Internet and Higher Education, 5,* 109–118.

Schank, R. C., & Abelson, R. P. (1977). *Scripts, plans, goals and understanding: An inquiry into human knowledge structures* (Vol. 2): Lawrence Erlbaum Associates Hillsdale, NJ.

Schneider,W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. Psychological Review, 84, 1e66.

Schworm, S., & Renkel, A. (2006). Computer-supported examplebased learning: When instructional explanations reduce selfexplanations. Computers & Education, 46, 426–445.

Sherry, L. (1996). Raising the prestige of online articles. *Intercom, 43*(7), 25-43.

Simon, H. A. (1978). Information-processing theory of human problem solving. In W. Estes (Ed.), *Handbook of learning and cognitive processes* (Vol. 5, pp. 271-295). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Slotta, J. (2002). Designing the 'web-based inquiry science environment (WISE)'. *Educational Technology, 42*(5), 15–20.

Song, H. D., Grabowski, B. L., Koszalka, T. A., & Harkness, W. L. (2006). Patterns of instructional-design factors prompting reflective thinking in middle-school and college level problem-based learning environments. *Instructional Science, 34*(1), 63-87.

Sweller, J., & Levine, M. (1982). Effects of goal specificity on means-ends-analysis and learning. ***Journal of Experimental Psychology: Learning, Memory, and Cognition, 8,*** 463-474.

Sweller, J., Mawer, R., &Ward, M. (1983). Development of expertise in mathematical problem solving. ***Journal of Experimental Psychology: General, 112,*** 639-661.

Sweller, J., & Cooper, G. A. (1985). The use of worked examples as a substitute for problem solving in learning algebra. *Cognition and Instruction, 2*(1), 59-89.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*(2), 257-285.

Sweller, J. (1993). Some cognitive processes and their consequences for the organisation and presentation of information. *Australian Journal of Psychology. 45*(1) 1-8

Sweller, J., Merriënboer, J. J. G. v., (1959), & Paas, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*(3), p. 251-296.

Sweller, J. (1994). Cognitive load theory, learning difficulty and instructional design. Learning and Instruction, 4, 295–312.

Tarmizi, R. A., & Sweller, J. (1988). Guidance during mathematical problem solving. Journal of Educational Psychology, 80, 424e436.

Thompson, S.D., Martin, L., Lynne, R., & Branson, D. (2003). Assessing critical thinking and problem solving using a web-based curriculum for students. *Internet and Higher Education, 6*(2), 185–191.

Uribe, D., Klein, J.D., & Sullivan, H. (2003). The effect of computer-mediated collaborative learning on solving ill-defined problems. *Educational Technology, Research and Development, 51*(1), 5–19.

van Merriënboer, J. J. G. (1997). Training complex cognitive skills: A four-component instructional design model for technical training. Englewood Cliffs, NJ: Educational Technology Publications.

van Merriënboer, J. J. G., Clark, R., & de Croock, M. B. M. (2002). Blueprints for complex learning: The 4C/IDModel. Educational Technology Research and Development, 50(2), 39–64.

van Gog, T., Paas, F., & van Merriënboer, J. J. G. (2004). Process-oriented worked examples: Improving transfer performance through enhanced understanding. Instructional Science, 32(1–2), 83–98.

van Merriënboer, J. J. G., & Ayres, P. (2005). Research on cognitive load theory and its design implications for e-learning. *Educational Technology Research and Development, 53*(3), 5-13.

van Gog, T., Paas, F., & van Merriënboer, J. J. G. (2006). Effect of process-oriented worked examples on troubleshooting transfer performance. Learning and Instruction, 16, 154–164.

van Gog, T., Paas, F., & van Merriënboer, J. J. G. (2008). Effect of studying sequences of process oriented and product-oriented worked examples on troubleshooting transfer efficacy. Learning and Instruction, 18, 211–222.

VanLehn, K. (1996). Cognitive skill acquisition. Annual Review of Psychology, 47, 513e539.

Ward, M., & Sweller, J. (1990). Structuring effective worked example. Cognition and Instruction, 7(1), 1–39.

Wilson, B. & Cole, P. (1996). Cognitive teaching models. In D. Jonassen (Ed.) Handbook of Research in Instructional Technology. New York: Scholastic Press.

Yu, W. F., She, H. C., & Lee, Y. M. (2010). The effects of web□based/non□Web□based problem□solving instruction and high/low achievement on students’ problem□solving ability and biology achievement. *Innovations in Education and Teaching International, 47*(2), 187-199.

Zawojewski, J., & Lesh, R. (2003). A models and modeling perspective on problem solving. *Beyond Constructivism: Models and Modelling Perspectives on Mathematics Problem Solving, Learning and Teaching*, 317-337.

Zhu, X., & Simon, H. A. (1987). Learning mathematics from examples and by doing. Cognition and Instruction, 4(3), 137–166.

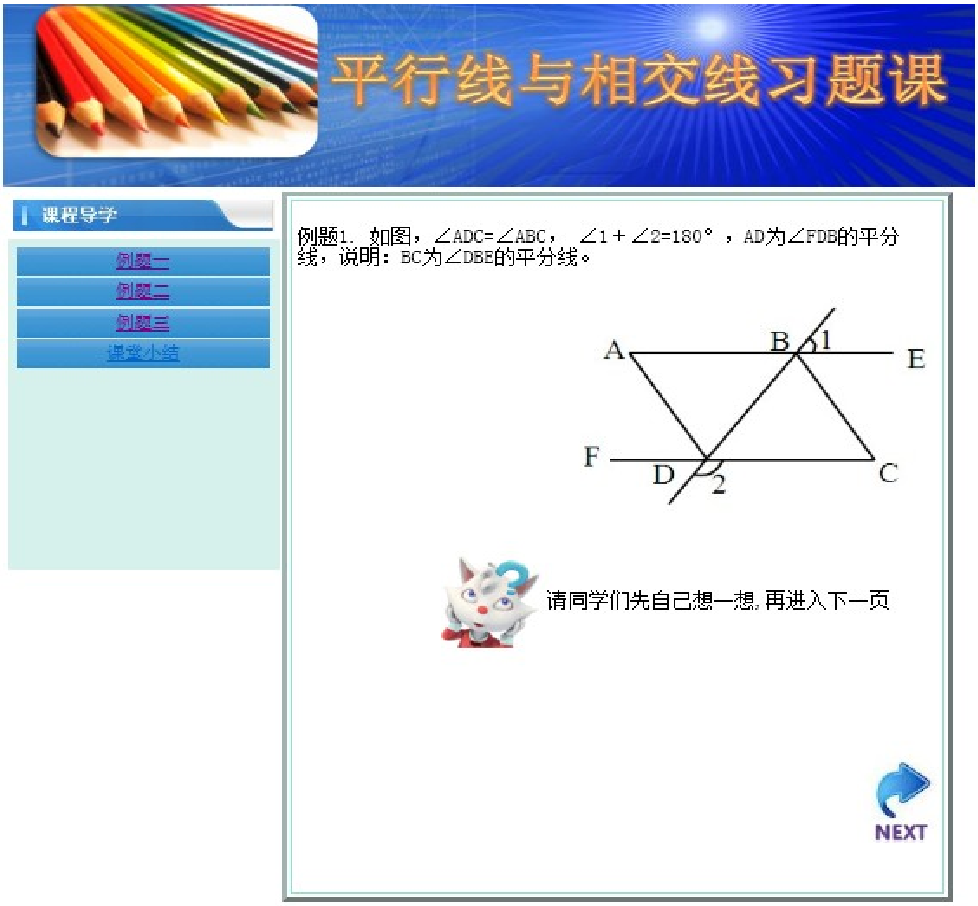
APPENDICES

APPENDIX A

WORKED EXAMPLE LESSON MATERIALS

Introduction & Learning Goals

The Statement for Task 1



Process-Oriented Worked Example for Task 1

课程导学

例题一

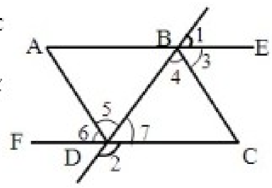
例题二

例题三

课堂小结

例题1. 如图，∠ADC=∠ABC， ∠1＋∠2=180°，AD为∠FDB的平分线，说明：BC为∠DBE的平分线。

分析： 从图形上看，AE应与CF平行，AD应与BC平行，不妨假设它们都平行，这时欲证BC为∠DBE的平分线，只须证∠3=∠4，而∠3=∠C=∠6，∠4=∠5，由AD为∠FDB的平分线知∠5=∠6，这样问题就转化为证AE∥CF，且AD∥BC了，由已知条件∠1＋∠2=180° 不难证明AE∥CF，利用它的平行及∠ADC=∠ABC的条件，不难推证AD∥BC。



证明：

∵∠1＋∠2=180°（已知） ∠2＋∠7=180°（补角定义）
∴∠1=∠7（同角的补角相等）
∴AE∥CF （同位角相等，两直线平行）
∴∠ABC＋∠C=180°（两直线平行，同旁内角互补）
又∠ADC=∠ABC（已知），CF∥AB（已证）
∴∠ADC＋∠C=180°（等量代换）
∴AD∥BC（同旁内角互补，两直线平行）
∴∠6=∠C， ∠4=∠5（两直线平行，同位角相等，内错角相等）
又∠3=∠C（两直线平行，内错角相等）
∴∠3=∠6（等量代换）
又AD为∠BDF的平分线
∴∠5=∠6
∴∠3=∠4（等量代换）
∴BC为∠DBE的平分线

Product-Oriented Worked Example for Task 1

The Statement for Task 2

Process-Oriented Worked Example for Task


平行线与相交线习题课

课程导学

例题一

例题二

例题三

课堂小结

例题2. 如图，已知AB // CD. （1）猜想∠1， ∠2，∠3之间的关系；（2）证明你的猜想.

分析： 猜想∠1=∠2+∠3，如图所示，试想将∠1分成两部分， 一部分等于∠3，只要剩下的部分等于∠2 ，即可得到证明，过A点作EC的平行线FG交CD于点H，那么 ∠3=∠EAF，如图所示，只要∠FAB=∠2即可得到证明。

证明：

过A点， 作EC的平行线FG交CD于点H

∵EC//FG

∴∠EAF=∠3（ 两直线平行，内错角相等 ）

∴∠2=∠AHD（两直线平行，同位角相等）

∵ AB // CD，

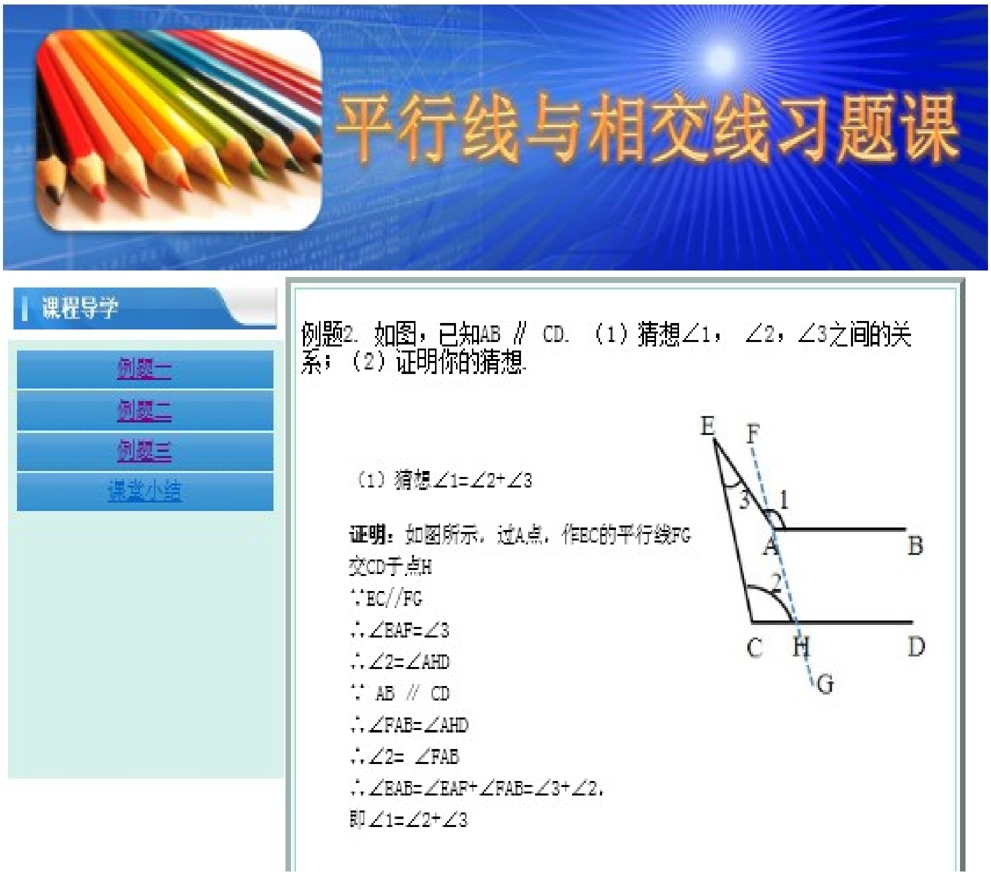
∴∠FAB=∠AHD（两直线平行，同位角相等）

∴∠2= ∠FAB（等量代换）

∴∠EAB=∠EAF+∠FAB=∠3+∠2，

即∠1=∠2+∠3

Product-Oriented Worked Example for Task 2



The Statement for Task 3

Process-Oriented Worked Example for Task 2

课程导学

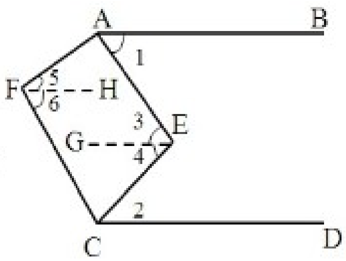
例题一
例题二
例题三
课堂小结

例题3．（1）如图一， 已知AB//CD，$\angle EAB=\frac{1}{3}\angle BAF$， $\angle ECD=\frac{1}{3}\angle DCF$，试说明$\angle F=360^\circ-3\angle E$

（2）如图二，若AB//CD，$\angle EAB=\frac{1}{5}\angle BAF$， $\angle ECD=\frac{1}{5}\angle DCF$，则$\angle F=360^\circ$-______$\angle E$（直接填入答案，不必说明理由）；

（3）若AB//CD，$\angle EAB=\frac{1}{n}\angle BAF$， $\angle ECD=\frac{1}{n}\angle DCF$，则$\angle F$与$\angle E$的数量关系（用含有n的代数式表示）．

分析： 由已知AB//CD，若要说明$\angle F=360^\circ-3\angle E$，则需得到$\angle E$与$\angle 1$、$\angle 2$的关系，过点E作AB的平行线EG，可证$\angle E=\angle 1+\angle 2$，过点F作AB的平行线FH，可证$\angle BAF+\angle AFC+\angle DCF=360^\circ$，由已知可得 $\angle BAF=3\angle 1$，$\angle DCF=3\angle 2$，可证 $\angle AFC=360^\circ-3\angle E$



证明： 过点E做EG//AB，过点F作FH//AB

（1）∵EG//AB

∴$\angle 1=\angle 3$（两直线平行，内错角相等）

∵AB//CD

∴EG//CD（如果两条直线都与第三条直线平行，那么这两条直线也互相平行）

∴$\angle 4=\angle 2$ （两直线平行，内错角相等）

∵ $\angle AEC=\angle 3+\angle 4$

∴$\angle AEC=\angle 1+\angle 2$（等量代换）

∵FH//AB

∴$\angle BAF+\angle 5=180^\circ$（两直线平行，同旁内角互补）①

∵AB//CD

∴FH//CD（如果两条直线都与第三条直线平行，那么这两条直线也互相平行）

∴$\angle 6+\angle DCF=180^\circ$（两直线平行，同旁内角互补）②

∴$\angle BAF+\angle 5+\angle 6+\angle FCD=\angle BAF+\angle AFC+\angle DCF=360^\circ$ （将①和②相加可得出）

即$\angle AFC=360^\circ-(\angle BAF+\angle DCF)$

又∵$\angle 1=\frac{1}{3}\angle BAF$， $\angle 2=\frac{1}{3}\angle DCF$（已知）

∴$\angle BAF=3\angle 1$ $\angle DCF=3\angle 2$

∴$\angle AFC=360^\circ-(\angle BAF+\angle DCF)=360^\circ-(3\angle 1+3\angle 2)$

即 $\angle AFC=360^\circ-3(\angle 1+\angle 2)$

（2）由以上求解过程可知若$\angle EAB=\frac{1}{5}\angle BAF$， $\angle ECD=\frac{1}{5}\angle DCF$，

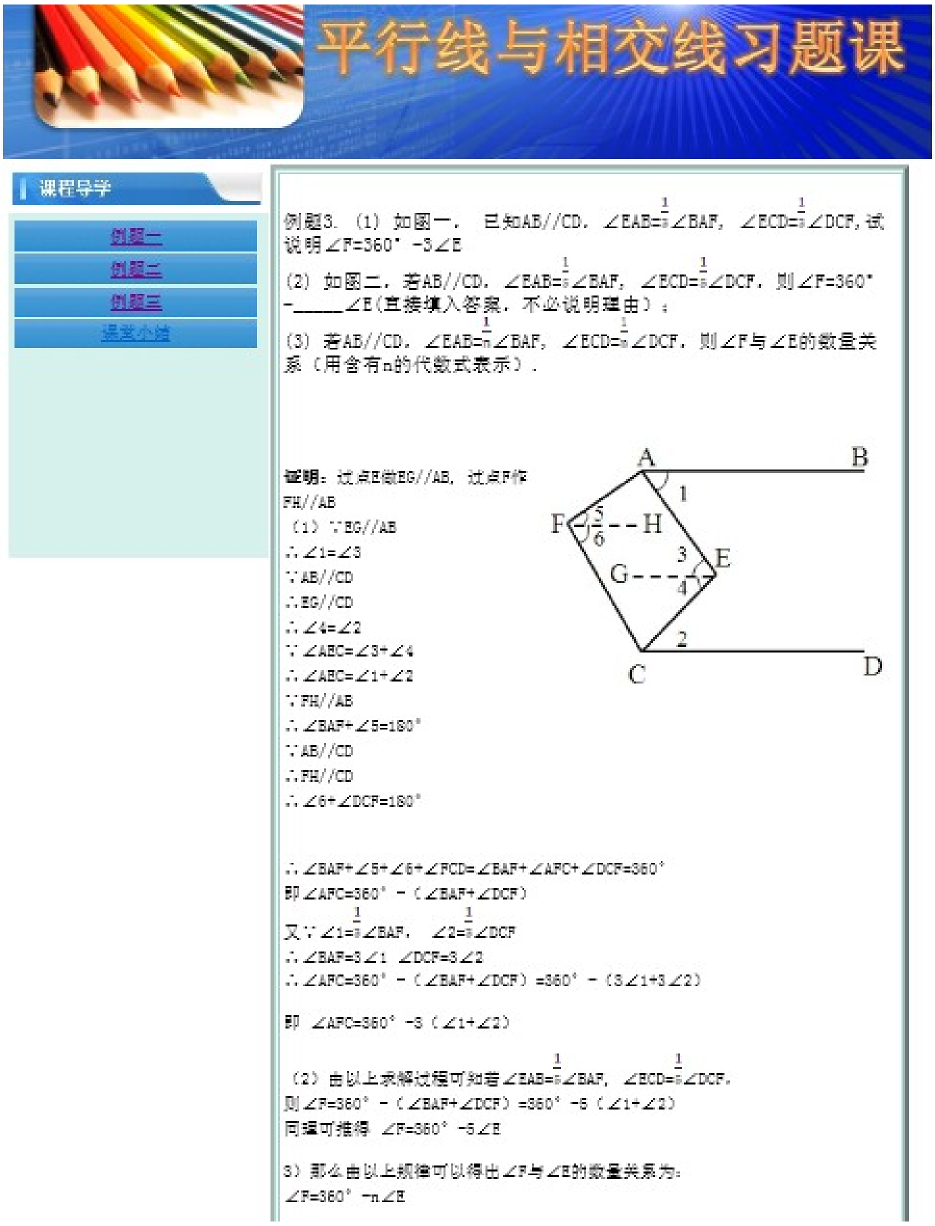
则$\angle F=360^\circ-(\angle BAF+\angle DCF)=360^\circ-5(\angle 1+\angle 2)$

同理可推得 $\angle F=360^\circ-5\angle E$

（3）那么由以上规律可以得出$\angle F$与$\angle E$的数量关系为：

$\angle F=360^\circ-n\angle E$

Product-Oriented Worked Example for Task 2



平行线与相交线习题课

课程导学

例题一

例题二

例题三

课堂小结

例题3. （1）如图一， 已知AB//CD，$\angle EAB=\frac{1}{3}\angle BAF$，$\angle ECD=\frac{1}{3}\angle DCF$，试说明$\angle F=360^\circ-3\angle E$

（2）如图二，若AB//CD，$\angle EAB=\frac{1}{5}\angle BAF$，$\angle ECD=\frac{1}{5}\angle DCF$，则$\angle F=360^\circ$-_____$\angle E$（直接填入答案，不必说明理由）；

（3）若AB//CD，$\angle EAB=\frac{1}{n}\angle BAF$，$\angle ECD=\frac{1}{n}\angle DCF$，则$\angle F$与$\angle E$的数量关系（用含有n的代数式表示）.

证明：过点E做EG//AB，过点F作FH//AB

（1）∵EG//AB

∴$\angle 1=\angle 3$

∵AB//CD

∴EG//CD

∴$\angle 4=\angle 2$

∵$\angle AEC=\angle 3+\angle 4$

∴$\angle AEC=\angle 1+\angle 2$

∵FH//AB

∴$\angle BAF+\angle 5=180^\circ$

∵AB//CD

∴FH//CD

∴$\angle 6+\angle DCF=180^\circ$

∴$\angle BAF+\angle 5+\angle 6+\angle FCD=\angle BAF+\angle AFC+\angle DCF=360^\circ$

即$\angle AFC=360^\circ-(\angle BAF+\angle DCF)$

又∵$\angle 1=\frac{1}{3}\angle BAF$，$\angle 2=\frac{1}{3}\angle DCF$

∴$\angle BAF=3\angle 1$ $\angle DCF=3\angle 2$

∴$\angle AFC=360^\circ-(\angle BAF+\angle DCF)=360^\circ-(3\angle 1+3\angle 2)$

即 $\angle AFC=360^\circ-3(\angle 1+\angle 2)$

（2）由以上求解过程可知若$\angle EAB=\frac{1}{5}\angle BAF$，$\angle ECD=\frac{1}{5}\angle DCF$，

则$\angle F=360^\circ-(\angle BAF+\angle DCF)=360^\circ-5(\angle 1+\angle 2)$

同理可推得 $\angle F=360^\circ-5\angle E$

3）那么由以上规律可以得出$\angle F$与$\angle E$的数量关系为：

$\angle F=360^\circ-n\angle E$

APPENDIX B

PRE-TEST

测试说明：　　　班级__________　　　姓名__________

本试卷仅用于教育研究，测试成绩仅供研究参考，绝对保密，请同学们独立完成，请勿抄袭。测试时间：30 分钟

一. 选择题（5 个）

1. 如图 1，要得到 a∥b，则需要条件（　　）

A. ∠2＝∠4　　　　B. ∠1＋∠3＝180°

C. ∠1＋∠2＝180　　　　D. ∠2＝∠3

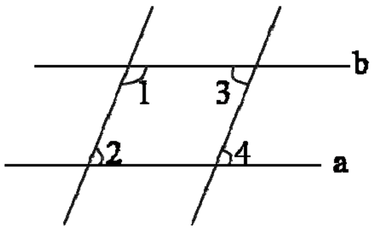


图 1

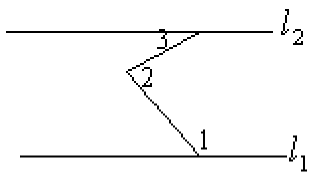


图 2

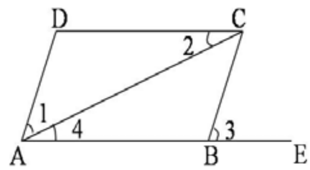
2. 如图 2 所示，l_1 ∥ l_2，∠1＝115°，∠3＝30°，则∠2＝（　）

A. 85°　　　B. 95°　　C. 90°　　D. 100°

3. 如图 3 所示， 已知 AB//CD, AD//BC, ∠ABE 是平角，则下列说法中正确的是（　）

A. ∠1=∠2＞∠3

图 3



B. ∠1+∠2 = ∠3

C. ∠1+∠2 < ∠3

D. ∠1+∠2 与∠3 的大小没有关系

4. 已知：如图 4，∠AOB 的两边 *OA*、*OB* 均为平面反光镜，∠*AOB*＝40°，在 *OB* 上有一点 *P*，从 *P* 点射出一束光线经 *OA* 上的 *Q* 点反射后，反射光线 *QR* 恰好与 *OB* 平行，入射光线和反射光线与平面镜的夹角分别是入射角和反射角，而且入射角等于反射角，则∠*QPB* 的度数是（　）

A. 60°　　B. 80°　　C. 100　　D. 120°

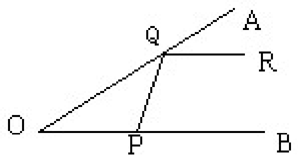


图 4

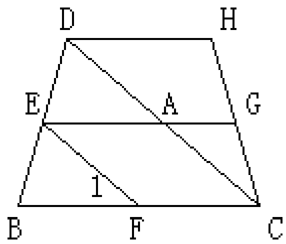


图 5

5．如图 5，DH∥EG∥BC，且 DC∥EF，则图中与∠1 相等的角（不包括∠1）的个数是（　）

A. 2　　B. 4　　C. 5　　D. 6

二. 填空题 （5 个）

1．A 是直线 a 外一点，B 是直线上一点，A 到 a 的距离为 3cm，那么 AB____3cm。

2. 如图 6，a∥b，AB⊥a 垂足为 O，BC 与 b 相交于点 E，若∠1=34°，则∠2=___________。

3. 如 图 7，$AB \parallel CD$，直 线 l 平 分 $\angle AOE$，$\angle 1 = 40°$，则 $\angle 2 =$ ___________.

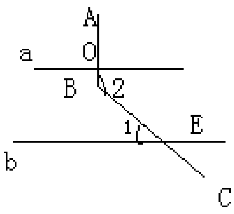


图 6

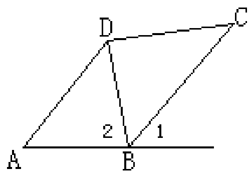


图 7

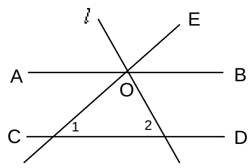


图 8

4．如 图 8，AD∥BC，∠1=60°，∠2=50°，则 ∠A=_______，∠CBD=_______，∠ADB=_______

5．将一张长方形纸条 ABCD 沿 EF 折叠，如图 9 所示，如果∠2=105°，则∠1=_______.

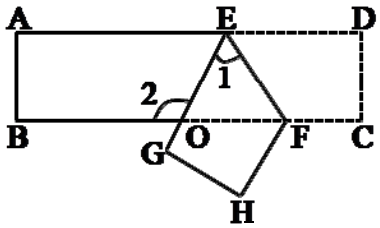


图 9

三、解答题 (3 个)

1. 如图 10，已知∠1=∠2，∠D=∠3，求证：DB//EC.

证：∵∠1=∠2

∴（　）∥（　）（　　　　　），

∴∠D=（　　）（　　　　　　）

又∵∠D=∠3（已知）

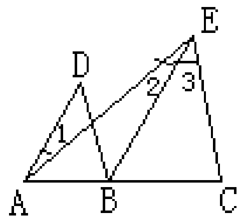


图 10

∴∠（　　）=∠（　　）

∴（　　）∥（　　）（　　　　　　　）

2. 如图 11，$AB // CD$，AE 平分 $\angle BAD$，CD 与 AE 相交于 F，$\angle CFE = \angle E$。求证：$AD // BC$

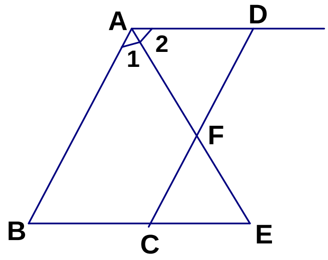


图 11

3.如图 12，∠AOB 形纸片沿 CD 折叠，若 O'C//BD，那么 O'D 与 AC 平行吗？请说明理由.

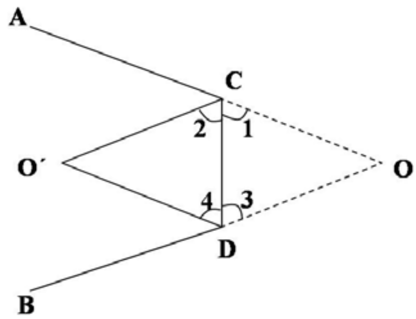


图 12

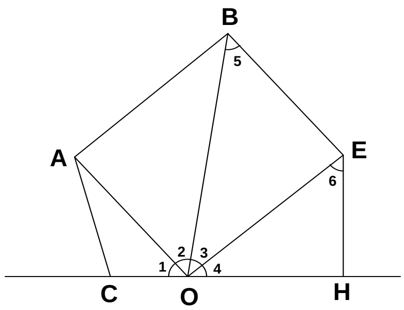
APPENDIX C

POST-TEST

班级____________姓名：___________

请同学根据所学习的内容，完成以下练习题目：

1. 图 11，BE∥AO，AO 是∠COB 的角平分线，OE⊥OA 于点 O，EH⊥CO 于点 H，那么∠5=∠6，说明为什么？



鬲（11）

2.（1） 如图 1，已知 AB∥CD，请猜想图形中的∠A、∠C、∠P 的数量关系，并尝试说明你的理由。

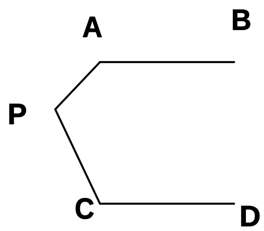


图 1

（2）如图 2 和图 3，已知 AB∥CD，分别猜想下列两个图形中的∠A、∠C、∠P 的数量关系，并选其中一种情况说明理由。

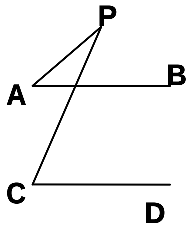


图 2

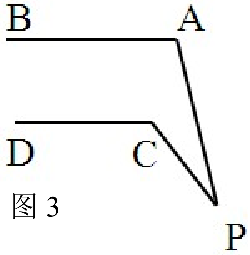


图 3

3. (1) 如图 1，已知 AB//CD，∠EAF=$\frac{1}{2}$∠EAB，∠ECF=$\frac{1}{2}$∠ECD,试说明∠AFC=$\frac{1}{2}$∠AEC;

(2) 如图 2，若 AB//CD，∠EAF=$\frac{1}{4}$∠EAB，∠ECF=$\frac{1}{4}$∠ECD，则∠AFC=______∠AEC（直接填入答案，不必说明理由）；

（3）若 AB//CD，∠EAF=$\frac{1}{n}$∠EAB，∠ECF=$\frac{1}{n}$∠ECD，则∠AFC 与∠AEC 的数量关系（用含有 n 的代数式表示）

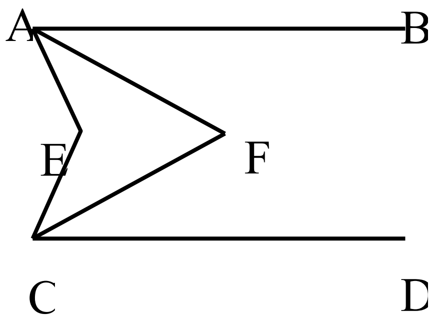


图 1

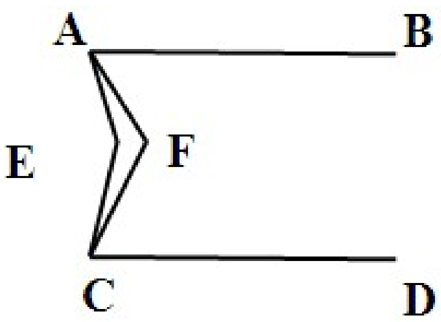


图 2

APPENDIX D

MENTAL EFFORT SURVEY

Mental Effort Scale: Using the 9-point scale below, rate the amount of mental effort you exerted during the activity you have just finished.

Circle One

1. = Very, very low mental effort
2. = Very low mental effort
3. = Low mental effort
4. = Rather low mental effort
5. = Neither low nor high mental effort
6. = Rather high mental effort
7. = High mental effort
8. = Very high mental effort
9. = Very, very high mental effort

국문초록

문제 해결을 위한 예제 유형과 사전 지식 수준이 인지부하와 학업성취도에 미치는 영향

양 연

서울대학교 대학원

교육학과 교육공학 전공

본 연구의 목적은 웹 기반 문제 해결 학습상황에서 예제 유형과 사전 지식 수준이 학습자의 인지부하와 학업성취도에 어떠한 영향을 미치는지를 알아보는 데에 있다. 이를 위해 본 연구에서는 예제 유형을 과정지향 예제로 이루어진 프로그램과 산출물 지향 예제로 이루어진 프로그램으로 구분하고, 학습자를 사전지식 수준 상위 40% 집단과 하위 40% 집단으로 구분하여 다음과 같이 연구문제를 설정하였다.

첫째, 웹 기반 문제 해결 학습환경에서 예제 유형에 따라 학업성취도에 유의미한 차이가 있는가?

둘째, 웹 기반 문제 해결 학습환경에서 예제 유형과 사전 지식 수준은 인지부하에 상호작용 효과가 있는가?

셋째, 웹 기반 문제 해결 학습환경에서 예제 유형과 사전 지식 수준은 학업성취도에 상호작용 효과가 있는가?

연구문제를 검증하기 위해 중국 한 S 중학교 1 학년에 재학 중인 152 명을 대상으로 실험을 수행하였다. 연구에서 사용된 실험도구는 사전 지식 검사, 웹기반 문제 해결학습 프로그램, 사후 인지부하 검사, 학업 성취도 검사 등이 있다. 예제 유형과 사전 지식 수준에 따른 각각 두 개의 집단, 총 네 개의 실험집단이 웹 기반 문제 해결 학습을 수행한 후 인지부하와 학업성취도를 살펴보았다.

본 연구를 통해 토출된 연구결과를 요약하면 다음과 같다.

첫째, 웹 기반 문제 해결 학습환경에서 예제 유형에 따라 학업성취도에 유의미한 차이가 나타나지 않았다 ($T=.405$, $P>.05$).

둘째, 웹 기반 문제 해결 학습환경에서 예제 유형과 사전 지식 수준은 인지부하에 상호작용 효과가 나타났다 ($F=4.194$, $P<.05$). 사전 지식 수준이 높은 집단은 산출물 지향 예제에 대하여 인지부하를 적게 느꼈고, 사전 지식 수준이 낮은 집단은 과정 지향 예제에 대하여 인지부하를 적게 느낀 것으로 나타났다.

셋째, 웹 기반 문제 해결 학습환경에서 예제 유형과 사전 지식 수준은 학업성취도에 상호작용 효과가 나타나지 않았다 ($F = .052$, $P >.05$).

본 연구의 결과, 문제 해결에 있어서 예제 유형에 따른 사전 지식 수준이 인지부하에 긍정적인 효과를 미치는 것으로 밝혀졌다. 이러한 연구결과는 문제 해결 학습환경에서 학습자의 사전 지식 수준을 고려하여 다양한 예제를 설계할 할 필요가 있음을 시사한다.

주요어 : **문제해결, 예제 유형, 과정 지향 예제, 산출물 지향 예제, 사전 지식, 인지부하**

학 번 : **2010-24150**